THE MODERN TRUCK, DESIGN, CONSTRUCTION, OPERATION, REPAIR, ...

Victor Wilfred Pagé

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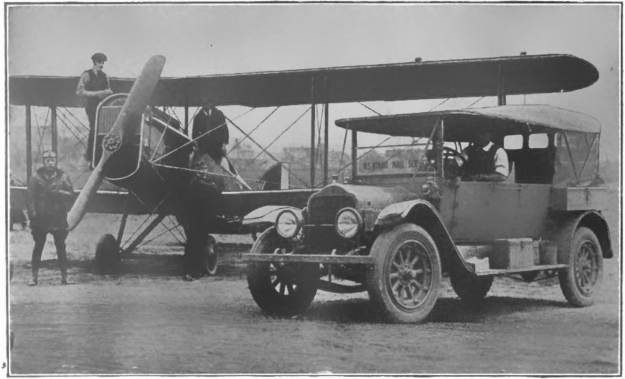
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THE MODERN
MOTOR TRUCK

DESIGN, CONSTRUCTION, OPERATION, REPAIR
COMMERCIAL APPLICATIONS

A COMPLETE TREATISE ON ALL FORMS OF MOTOR TRUCKS PROPELLED BY GASOLINE OR ELECTRIC POWER, CONSIDERING IN DETAIL EVERYTHING ONE NEEDS TO KNOW ABOUT MOTOR TRUCKS, THEIR CARE, OPERATION AND ECONOMICAL USE

INCLUDES
FULL INSTRUCTIONS, IN SIMPLE LANGUAGE, FOR HANDLING ALL LEADING MAKES OF TRUCKS AND MAKING NECESSARY REPAIRS. SHOWS ALL TYPES OF SPECIAL BODIES. INVALUABLE TO TRUCK OWNERS, CHAUFFEURS, TRAFFIC MANAGERS, SHOP SUPERINTENDENTS, TRUCK SALESMEN, MECHANICS AND REPAIR MEN. EVERY PHASE OF THE SUBJECT IS TREATED IN A PRACTICAL, NON-TECHNICAL MANNER

BY

VICTOR W. PAGÉ, M. E.

Member Society of Automotive Engineers, Author of "The Modern Gasoline Automobile," "The Ford Model T Car," etc.

Illustrated by 528 Specially Made Engravings

THE ILLUSTRATIONS DEFINING CONSTRUCTION OF PARTS ARE MADE FROM ACCURATE MOTOR TRUCK ENGINEERING DRAWINGS

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COMPOSITION, PLATING AND PRESS WORK
By PUBLISHERS PRINTING COMPANY, NEW YORK

PREFACE

This treatise has been prepared to meet an insistent demand from motor truck owners, users and drivers, especially those charged with their operation and mechanical care, for a complete text-book on this subject that would outline the principles on which trucks of various types operate. This exposition not only considers construction and operation of all leading types of gasoline and electric trucks, but also gives valuable data on systematic maintenance and cost system that will be valuable to those charged with the responsibility of operating truck fleets economically and efficiently.

It is the intention of the writer to cover the fundamental facts and principles of commercial vehicle construction briefly and in a non-technical manner. It is not offered to the reader as a scientific or engineering treatise, though all statements made will bear the light of scientific investigation, but as a compilation of practical information on truck construction, operation, maintenance and repair that would be of value to just that class of practical mechanic, truck driver and executive who wants a technical subject treated from an everyday standpoint. When so treated it will be understood without requiring that research and mathematical exposition that is the delight of the technician, but the bane of the busy man seeking only information he can use to advantage in his daily work.

Thorough mastery of basic principles on which the truck mechanism operates is necessary if one wishes to purchase motor vehicles intelligently or operate them economically. Through the cooperation of the Service Departments of the leading American motor truck makers, the author has been enabled to present considerably more practical operating and repair data than is usually found in a treatise of this character, and also to present a series of informative drawings and photographs such as have never before been gathered in one volume.

Interesting motor truck and trailer applications have been presented in wide variety, and the various types of special purpose and combination body designs that seem to have most merit have been selected from the mass of material made available to the author. The essential knowledge that is needed to make a man fully conversant with latest commercial vehicle practice is presented in a logical and systematic manner, and in a way that should be readily followed by anyone, even if not technically inclined or mechanically experienced. It is believed that this volume will fill a demand that has long existed, and that it merits the consideration of anyone interested in any of the various phases of modern transportation over the highways.

VICTOR W. PAGÉ.

February, 1921.

ACKNOWLEDGMENT

The preparation of a treatise of this comprehensive character would have been much more difficult than it was if the author had not received the whole-hearted cooperation of the leading firms in the motor truck industry, who furnished invaluable illustrative matter, such as special drawings and photographs, and much data regarding motor truck construction, care and operation. The service departments of various concerns mentioned in the book sent special instructions on the care and operation of their trucks. The various trade papers and Transactions of the S. A. E. were referred to for considerable information, and the author's thanks are also due to the Ordnance Branch of the U. S. Army for complete information on the various types of trucks used in the Army. In every case credit has been given for material abstracted to the source from which it was received. It is believed that the assistance of truck factory engineers and service experts have made the treatise distinctive, in that it is essentially practical and well suited to the needs of the general reader.

VICTOR W. PAGÉ.

February, 1921.

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THE MOTOR TRUCK

CHAPTER I

MOTOR TRUCK TYPES

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The motor truck has been used in every country of the world and for hauling all kinds of commodities. For certain classes of work it has almost entirely replaced horse drawn vehicles. It is not only popular in our cities but its use is becoming general in the rural communities where the horse reigned supreme only a few years ago. Motor trucking has been demonstrated to be cheaper than using horses, as shown definitely by figures presented by users of a few trucks as well as operators of large fleets. Trucks have greater radius than horse drawn vehicles, their endurance is greater because they are machines insensible to climatic conditions instead of being subject to all the ills horse flesh is heir to. Trucks are not free from trouble, by any means; they get out of repair and wear out in service. The troubles are easily located, however, and can be corrected by mechanical means, while the depreciation in service is a fixed charge that is reckoned in the operating costs.

Horse and Truck Compared.—The rate of travel of a truck is much greater than that of a horse drawn outfit, its radius of action three to five times as great. A good day's work for a team of horses is twenty miles, the average rate of travel is about three or four miles per hour and the average hauling ability is three tons. A motor truck can be driven 100 miles in a ten-hour day, as even the heaviest vehicles have a speed of ten miles per hour. Its hauling capacity may be six to ten tons, or twice to three times that of a team of horses. Mechanical means may be employed in unloading, the engine of the truck furnishing the power for a quick discharge of the load. This is seldom possible with animal power. Average figures indicate that it costs about twice as much to operate a five-ton truck as it does a team of horses. The team of horses will do sixty ton-miles work in a day, whereas the motor truck can do 500 ton-miles in the same period. Horses can only be used a certain period; a truck can be run as many hours per day as conditions demand. The five-ton motor truck would be as economical as a team of horses if it only hauled twice as much material; actually it does four times the work in a given time. When not in use, it costs nothing more than storage, interest on the investment and insurance to keep a truck. With draft animals it costs all of these items and feed and constant care besides. There is no doubt now in the minds of business men about the economy of intelligently directed motor haulage.

Trucking by automobile can be made very expensive if certain precautions are slighted, and be carried on very economically if it is undertaken in a business-like way. Knowledge of motor truck care and operation is essential to use trucks successfully. This can be best understood if motor truck construction and principles upon which they work are known. The purpose of this treatise is to give the present or prospective truck user or owner an opportunity to acquire the information needed in a logical manner.

Motor Truck Design.—The large demand for motor trucks from the European belligerents, coupled with a greatly increased sale in this country, has kept the motor truck builders so busy during the past year or so that but little time was spent in design development, although great improvements were made in details and construction, and production processes have been improved materially. Most of the makers were satisfied in continuing the designs that had been perfected at the close of 1917 as a result of the lessons learned by the severe service abroad, and it looks as though the truck of 1921 would not be very much different from its immediate predecessors. Last year's production of commercial vehicles was greater than that of any previous year, though the increase was not so marked as that of 1918 over its preceding year. The truck of 1921, however, will comprise a radically different construction from that of several years back. At that time the features of pleasure cars were beginning to be standardized, and the same desirable units were found in numerous cars of different makes that formerly differed widely from each other. The European war accelerated motor truck production, and as standardization is the most important fundamental underlying economical manufacture of goods in large quantities, truck designs became more and more alike through a growing realization of the advantages of certain methods of construction and combinations of elements.

Wide Range of Models Available.—Considering first the range of models available, there are more of the intermediate capacities now offered, though the average size is about the same as it has been for two years past, viz., 4,000 pounds or two tons capacity. There is a definite division into three main classes, the first being the delivery car; the second, the medium duty vehicle, and last, the heavy duty truck. Tractors are an entirely separate classification to be reckoned with because they have demonstrated their worth for heavy hauling in connection with trailers in an unmistakable way during the past several years. The first class includes capacities varying from 500 pounds to one ton; the second, from one ton to two and one-half tons; the third includes all vehicles of larger capacity than mentioned. Naturally, there is a great field for commercial vehicles coming into the first classification, and as the light chassis production is one easily carried out by the same methods developed for producing pleasure cars, their field of usefulness has been greatly increased because of the reduction in price possible by large output.

Delivery Cars Follow Passenger Car Practice.—Delivery cars usually follow pleasure car practice in most details and are largely built up of passenger car components. A marked tendency noted in even the smaller commercial models is a change to truck practice in some essentials. As most delivery cars are intended for higher speeds than commonly advised for commercial work, pneumatic tires are always used in light truck construction. Even when passenger car chassis designs are followed, the frames, springs, wheels and other parts are made more substantial than in a pleasure car of the same power. This is necessary because a truck is used every day and covers more ground than a passenger carrying car would. The average delivery car capacity is 1,500 pounds, and very few parcel cars of less than 1,000 pounds capacity are now being made. All those having one-ton capacity are not being built along truck lines, several entirely new designs being offered for the 1921 season that combine the mobility and speed of the lighter cars with the strength and ability to stand continuous service usually attributed only to the heavier designs. The improvements made in heavy duty trucks are detail changes intended for the most part to secure much greater structural strength. The general trend of modern truck design is clearly outlined in the composite truck shown at Fig. 1, while a typical high-grade truck of latest construction is shown in part section at Fig. 2, which depicts a Packard worm drive design.

The internal combustion motor is now the accepted power for motor trucks, though electrically propelled vehicles are used in many cities for short haul work when proper battery charging facilities are available. Steam-propelled trucks, which enjoy some degree of popularity for heavy hauling in England, are not used on American highways to any extent, only a few converted steam pleasure cars and buses being seen in service, and most of these in the New England States.

STATISTICS OF THE MOTOR TRUCK INDUSTRY

Truck Production in United States by Years

Source of Figures	Year	Number	Value Wholesale
United States Census	1914	25,375	$45,098,464
N. A. C. C. Estimate	1915	74,000	125,800,000
N. A. C. C. Estimate	1916	90,000	157,500,000
Automotive Products Section, War Industries Board	1917	128,157	220,982,668
Automotive Products Section, War Industries Board	1918	227,250	434,168,992
Automotive Products Section, War Industries Board (proposed)	1919	327,930	....

Very interesting statistics have been compiled in "Motor" which show the magnitude of the truck industry and its growth. Excerpts from these tabulations follow:

DISTRIBUTION OF PRODUCTION FOR 1919

(From reports by manufacturers to War Industries Board)

Capacity	Number	Per Cent.	Capacity	Number	Per Cent.	Capacity	Number	Per Cent.
½ ton	9,300	2.8	2 tons	49,947	15.2	4 tons	1,149	0.3
¾ ton	30,043	9.0	2½ tons	10,063	3.5	5 tons	16,992	5.1
1 ton	138,736	42.0	3 tons	6,155	1.8	5½ tons	1,000	0.3
1½ tons	43,308	13.2	3½ tons	19,212	5.9	6 tons	1,069	0.3
						7 tons	945	0.3

MISCELLANEOUS DATA

Companies actively engaged in truck manufacture in the United States	154
Motor trucks in use in the United States (estimated)	480,000
Transportation service rendered by motor trucks in United States last year (estimated ton-miles)	6,000,000,000
Cost of above service at 18 cents per ton mile	$1,080,000,000
Cost of same service by horse-drawn vehicle at 25 cents per ton-mile	$1,500,000,000
Estimated annual saving by use of Motor Truck	$420,000,000
Cost of hauling corn and wheat from farms by truck (U. S. Bureau of Crop Estimates report) per ton-mile	15 cents
Cost of same haulage by wagon (Bureau of Crop Estimates report) per ton-mile	30-33 cents

Important Components of Modern Trucks.—In this era of progress one would not hesitate to assert that the motor truck had been perfected or that it had reached a finality in design because the experience of the last few years would justify one in assuming that the principles of construction now applied so successfully may reasonably be considered permanent. The elements which have been proven essential to insure successful operation of all self-propelled vehicles, intended either for passenger or freight transport, may be easily defined as follows:

The mechanism should be as simple as it is possible to make it, as this promotes ease of repairing, facility in handling, and lessens the liability of trouble by reducing complications. The parts should be in proper proportion and arranged in such a manner relative to each other that one may be removed or replaced without disturbing other correlated appliances.

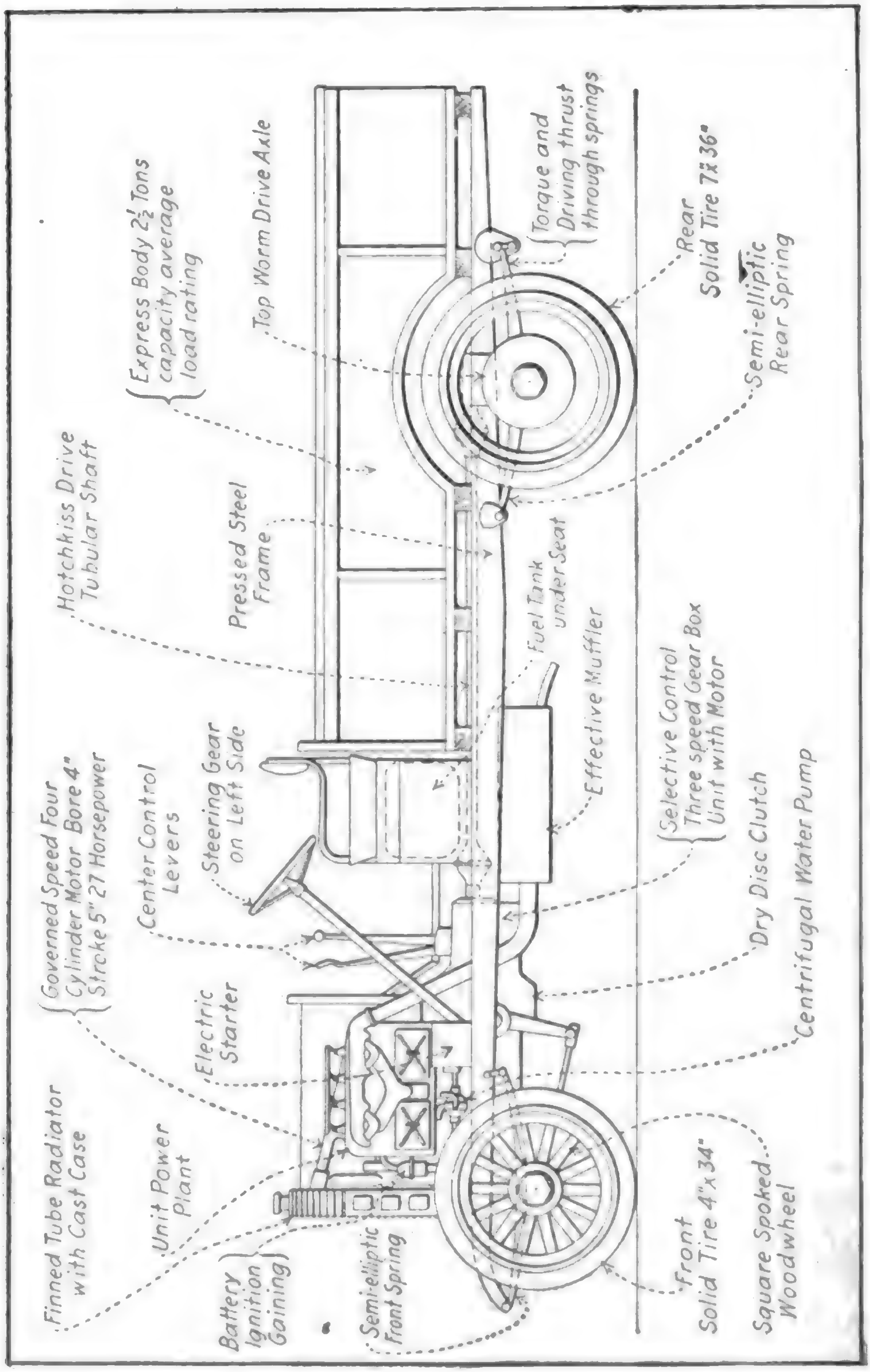
Finned Tube Radiator with Cast Case
Unit Power Plant
Battery Ignition Gaining
Semi-elliptic Front Spring
Governed Speed Four Cylinder Motor Bore 4" Stroke 5" 27 Horsepower
Electric Starter
Center Control Levers
Steering Gear on Left Side
Hotchkiss Drive Tubular Shaft
Pressed Steel Frame
Express Body 2½ Tons capacity average load rating
Top Worm Drive Axle
Fuel Tank under Seat
Effective Muffler
Torque and Driving thrust through springs
Front Solid Tire 4"x 34"
Square Spoked Woodwheel
Centrifugal Water Pump
Dry Disc Clutch
Selective Control Three speed Gear Box Unit with Motor
Semi-elliptic Rear Spring
Rear Solid Tire 7"x 36"

Fig. 1.—Composite Truck Showing Average Trend of Commercial Car Design.

The power furnished by a gasoline motor carried in the frame must be transmitted to the traction wheels or to the revolving shafts to which they are fastened with as little friction and power loss as is possible.

The driven wheels, usually the rear ones, though four-wheel and front-wheel drives are sometimes found, must be connected to some form of compensating or balance gear which enables each wheel to revolve independently of the other at times and at different velocities, because in turning corners the outer wheel describes a larger arc, and consequently a longer path, than the inner member. The differential gear was one of the most important elements which made for the successful development of the automobile, and at the present time special forms have been designed that have great merit in that they provide positive drive under all conditions.

The steering in most cases should be done by the two front wheels, which are carried at the ends of a yoked axle which is securely fastened to the chassis frame by means of the springs. The wheels are carried on steering knuckles which must be arranged to assume different angles when the vehicle is turning corners or deviates from a straight path in order to secure positive steering. On four-wheel drive commercial cars all wheels are sometimes used for steering.

Springs must be provided which will have sufficient strength and elasticity to neutralize vibration and allow for unevenness of the road surface by their yielding qualities, and thus reduce body movement. In order to relieve the machinery, running gear and passengers of the inevitable vibration which obtains at even moderate speed on ordinary roads the wheels should be provided with very resilient tires, preferably of the pneumatic or inflated forms for high speed cars, and cushion or solid rubber on the heavier and slower moving motor trucks.

The gas supply to the motor, the ignition of the charge, and the continuation of the engine cycle of operations should be automatic and require no attention from the operator after the motor is once started. To secure continued efficient operation, mechanical means must be provided for constant lubrication of all moving parts. All components which have movement relative to other parts should move with as little power loss by friction as possible, in order to conserve the available motor energy for tractive purposes. Anti-friction bearings of the ball

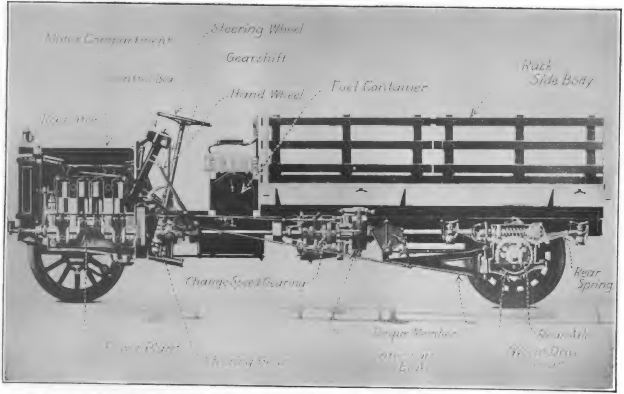
Motor Compartment
Steering Wheel
Gearshift
Hand Wheel
Fuel Container
Rack
Side Body
Change Speed Gearing
Torque Member
Rear Axle
Worm Drive
Rear
Spring

Fig. 2.—Part Sectional View of Packard Motor Truck Showing Arrangement of Important Power Generating and Transmitting Elements.

or roller type should be employed on all rotating shafts in the power plant, transmission system, and in the wheels, to save power, lubricant and reduce depreciation.

The center of gravity must be carried relatively low, which involves placing the body as close to the ground as practical considerations will permit. The wheel base, which is the distance between front and rear wheel centers, should be long, in order to secure the best results in tractive effort, steering, easy riding, and use of a body of proper size to carry the load. The power plant and other essential mechanism should be carried on a frame in such a manner that road shocks will not be transmitted and so coupled together that no frame distortion will produce disalignment of the driving shafts.

The control elements must be designed with a view to easy handling. This means that the steering gear should be irreversible—i.e., the hand wheel should not be affected by side movement of the front wheels, thus relieving the driver's arm of all undue strain while driving. Motor regulation should be by levers placed convenient to the driver's hands or feet, and gear shifting should be accomplished without difficulty. Powerful brakes must be employed to insure positive check of vehicle motion whenever it is desired to bring the conveyance to a stop. It is evident that the levers through which the brakes are operated should be so proportioned that a minimum of effort on the part of the operator will serve to check the vehicle immediately. Electric engine starting systems should be fitted and electric lighting is desirable.

The gradual modification of the automobile truck from a crude mechanism to a practical product has been attained over a period of about twenty years without radical changes that many confidently forecasted at the inception of the industry. The essential elements of the truck of today remain practically the same as far as basic principles are concerned as those which formed the basis of the first motor car. Only the details have been changed, and the forms which have resulted from the gradual process of evolution show a steady tendency toward uniformity of design in essentials, though there may be considerable difference in location of units and types of mechanism employed for a given purpose.

Truck and Wagon Construction Compared.—In the horse-drawn trucking vehicle there is no necessity for a heavy or

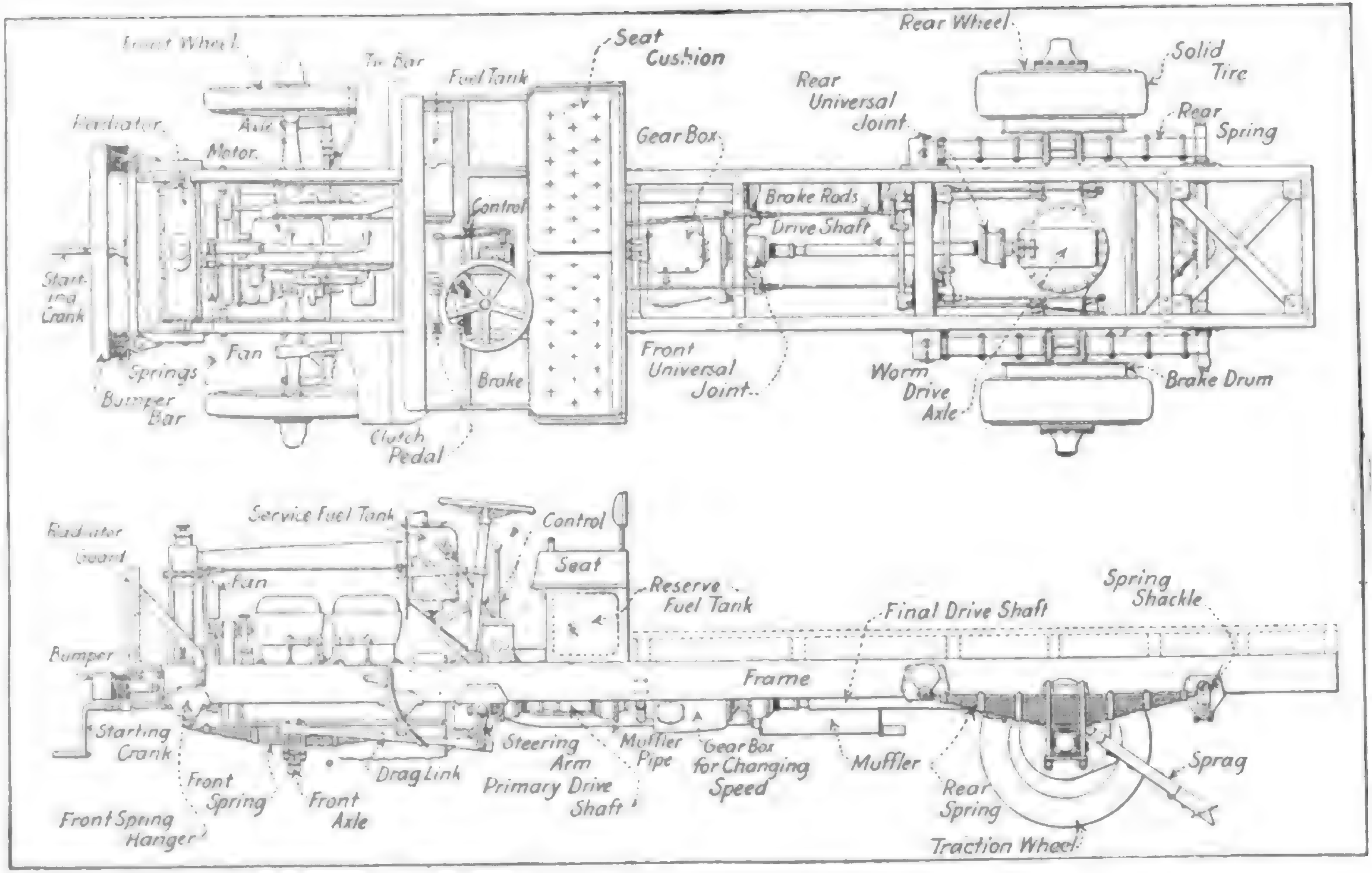
Front Wheel
Tie Bar
Fuel Tank
Seat Cushion
Rear Wheel
Solid Tire
Rear Universal Joint
Rear Spring
Radiator
Axle
Motor
Gear Box
Brake Rods
Drive Shaft
Control
Starting Crank
Fan
Springs
Bumper Bar
Brake
Front Universal Joint
Worm Drive Axle
Brake Drum
Clutch Pedal
Service Fuel Tank
Control
Radiator Guard
Seat
Fan
Reserve Fuel Tank
Spring Shackle
Final Drive Shaft
Bumper
Frame
Starting Crank
Steering Arm
Muffler Pipe
Gear Box for Changing Speed
Muffler
Sprag
Front Spring
Drag Link
Primary Drive Shaft
Rear Spring
Front Axle
Front Spring Hanger
Traction Wheel

Fig. 3.—Standardized U. S. Army Truck, Showing Location of Important Parts.

strong supporting frame, because the heavy truck body construction makes it possible to attach the springs directly to the sills on which the body rests. In a motor vehicle, however, the frame is usually separate from the body work, because it is often necessary to remove the body to gain access to some portion of the mechanism which may need attention, and also to fit various body designs on the same chassis. The frame of an automobile truck must be strong, because the engine and parts of the transmission system are installed thereon, and also because the speed possibilities of the automobile make it necessary that the frame be of sufficient strength to resist the stresses due to truck movement when driven over uneven road surfaces. These strains are not present in other forms of conveyances.

The steam locomotive which is capable of high speed and which is very heavy, travels on a smooth track, while ordinary horse-drawn trucks are not affected materially by the roughness of the path on which they travel because of their low speed and light weight. In the frame, or chassis group, one may include the main frame, sub-frame, steering gear, clutch and brake pedals, hand levers for varying change speed gear ratios, and applying emergency brakes; the front axle and its steering connections, the driving axle and brakes, the wheels, the tires, and the springs which form a yielding connection between the axles and the frame.

The power plant of a gasoline truck is composed of a number of distinct devices of which the engine proper is the most important, though all of them are necessary to insure practical operation. In order to describe power plant construction logically, it may be divided into five distinct assemblies, each of which may be resolved into the various parts of which they are composed. The most important is the engine itself, then the various auxiliary groups, such as the cooling system, the ignition apparatus, the carburetor and fuel system, and the lubrication or oiling appliances. One who understands horse-drawn vehicle construction will find many parts similar to those in wagons doing duty in the motor vehicle running gear.

Parts of Typical Trucks and Their Functions.—A brief explanation of the function of each part of the truck chassis depicted at Figs. 2 and 3 will serve to afford a better understanding of the construction of an automobile. The purpose of the front axle is not unlike that of a horse-drawn vehicle, while it is much different in construction. The wheels are installed on movable spindles, or steering knuckles, which are supported by yokes permitting one to move the wheels for steering rather than turning the entire axle on a fifth wheel, or jack-bolt arrangement as in a horse-drawn vehicle. This axle is attached to the frame by spring members which allow a certain degree of movement without producing corresponding motion of the frame.

The radiator, which is most often placed directly on the frame ahead of and over the axle in front of the motor, is employed to hold part of the water used in keeping the engine cool, and is an important part of the heat-radiating system. The starting handle is a crank by which the motor crankshaft is given sufficient initial movement by the operator to start the engine. The tie-bar joins the arms of the steering spindles on which the wheels revolve, and insures that these will swing together and in the same direction, either to the right or left. The steering link, often called the "drag link," connects one of the steering knuckles of the front axle with the steering gear.

The motor may be one of the various forms to be described, but all motor trucks, with but two exceptions, use four-cylinder, four-cycle engines. One truck employs a two-cylinder, another a six-cylinder power plant, but these are exceptions to established practice. The dash is a wooden or metal partition placed back of the power plant to separate the engine from the seating compartment. It is often employed to support some of the auxiliary apparatus necessary to motor action or some of the control elements.

The clutch is a device operated by a pedal, which permits the motor power to be coupled to the gearset, and from thence to the driving wheels or interrupted at the will of the operator. It is used in starting and stopping the truck and whenever the change speed gears are shifted.

The accelerator is a small pedal which actuates a valve on the gas supply device to permit more explosive mixture being fed to the engine when it is desired to increase the motor speed. Its function is comparable to that of the throttle of a steam engine or the controller of an electric vehicle. The pedals are foot-operated levers, one of which releases the clutch, the other applies the running brakes.

The motor control levers on the steering column are used in conjunction with the accelerator to vary the rotative speed of the motor, and thus regulate the energy produced in proportion to the work to be performed. The emergency brake lever applies a powerful braking member when it is desired to stop the truck quickly, and also when one wishes to lock the brakes if car movement is arrested on a down grade. The change speed lever operates the sliding gearing, which is utilized to produce varying ratios of velocity between the engine shaft and the rear wheels. The steering wheel actuates the mechanism which moves the wheels to the right or left when one wishes to describe the circle, turn a corner, dodge an obstacle, or otherwise deviate from a straight course.

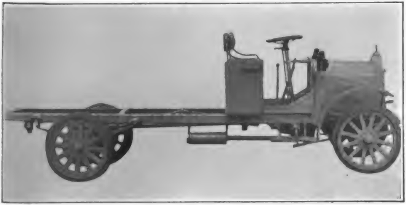

Fig. 4.—Side View of Chassis of Selden One-and-One-Half-Ton Truck.

The change speed gear is one of the most important elements of the power transmission system, and in connection with the clutch it is much used in operating and controlling the vehicle. The exhaust pipe is employed to convey the inert gases discharged from the motor cylinders to a device known as the muffler, which is designed to reduce gas pressure by augmenting the volume and thus diminish the noise made as it issues to the atmosphere. The driving shaft transmits power from the change speed gearset to the drive gearing in the rear axle.

A universal joint is a positive connection which permits a certain degree of movement between two shafts which must be driven at the same speed. One or the other, or both, may move in a lateral or vertical plane to a limited extent without interrupting the drive or cramping the moving parts. The rear construction houses the differential and driving gears, and the shafts or axles which transmit the power to the traction wheels.

Brakes are used to retard, or stop, the movement of the wheels, and are operated by rods which transmit the force the operator applies at the brake pedal or hand lever to the brake band. Torque or radius members are used to maintain a definite relation between the driving gears in the axle and those in gearset, and to take the driving thrusts off the axle and the strains imposed by braking and driving from the springs. The principles underlying operation of each of the parts shown and a number of different forms in which they may exist will be described more extensively in the chapters dealing fully with the various groups.

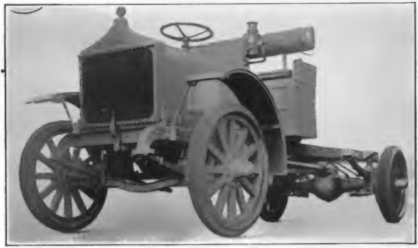

Fig. 5.—Three-quarter Front View of Selden One-and-One-Half-Ton Truck.

There is considerable diversity noted in the location of the various parts, methods of power transmission, etc. In one truck the change speed gearing may be incorporated with the engine to form a unit power plant. In some chain drive models it may be assembled with the countershaft. In still other designs it may be a separate member located amidships, and independent of the motor. In some truck designs, as at Fig. 7, one finds the motor under the seat or floor; in nearly all others it is placed at the front end of the chassis, as shown in most of the chassis illustrations. The reader may easily familiarize himself with these peculiarities of design by studying the various chassis designs given as examples of current practice.

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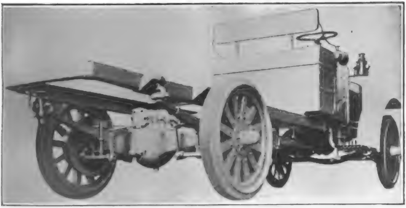

Fig. 6.—Three-quarter Rear View of Selden One-and-One-Half-Ton Truck Showing Worm-Drive Axle and Rear Spring Suspension.

Power Transmission by Shaft Drive.—The power of the engine in Diagram A, Fig. 11, is transmitted to the rear wheels in the following manner: The power developed by the engine is first transmitted from the flywheel, attached to the crankshaft of the engine, to the transmission or gear box, through the clutch. The clutch normally is engaged so that, as long as the gears are in mesh and the engine running, power will be trans-

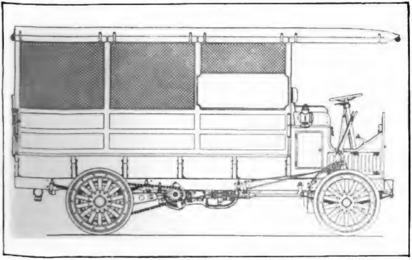

Fig. 7.—Showing Old Style Motor Truck Design in which Power Plant is Placed Under Operator's Feet, Thus Providing More Carrying Space for Body Without Lengthening the Wheel Base.

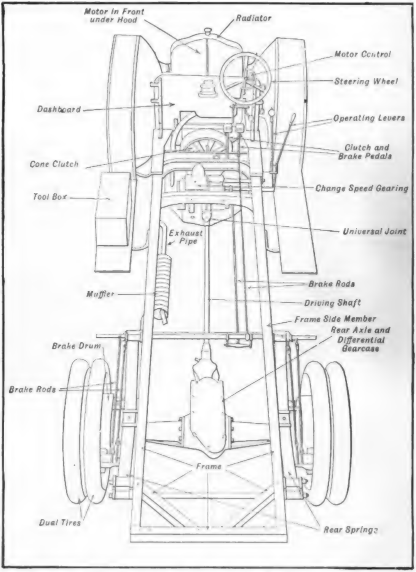
Motor in Front under Hood
Radiator
Motor Control
Steering Wheel
Dashboard
Operating Levers
Clutch and Brake Pedals
Cone Clutch
Change Speed Gearing
Tool Box
Universal Joint
Exhaust Pipe
Brake Rods
Muffler
Driving Shaft
Frame Side Member
Rear Axle and Differential Gearcase
Brake Drum
Brake Rods
Frame
Dual Tires
Rear Springs

Fig. 8.—**Light Motor Truck Chassis which Follows Typical Passenger Vehicle Design Except in Size of Parts. The Frame and Running Gear Components are Heavier and Stronger to Compensate for the Greater Load Carrying Capacity.**

mitted through the clutch and to the rear wheels. To disconnect the engine from the rear wheels it is only necessary to depress the clutch pedal.

Four forward gear ratios, or "leverages," are provided in the transmission or gear box by means of selective sliding spur gears. From the transmission the power is transmitted through a universal joint to the propeller shaft, through the universal on the rear of the propeller shaft, and then to the pinion shaft.

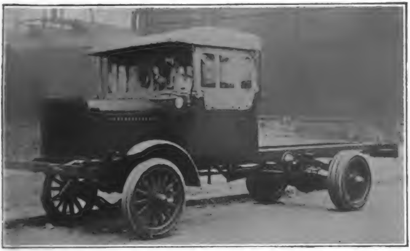

Fig. 9.—View of Standardized Chassis Used by the U. S. Army. This Type is Known as the Air Service Model.

In the rear axle the power is delivered uniformly to the two wheels by means of a bevel gear differential.

In Diagram B the engine is shown in the upper right hand corner, and the internal gears, which are attached to each of the rear wheels, in the lower left hand corner of the sketch. The power is transmitted from the engine through its flywheel to the cone clutch, which is operated by a clutch pedal. When the latter is depressed, the clutch is disconnected from the engine, and this, in turn, disconnects the power from the rear wheels. From the clutch the power is transmitted through the gear box, in which there are various speed gears. Three speeds forward and one reverse are provided.

From the transmission, the power is delivered to the rear axle by a tubular propeller shaft and two universal joints, one at either end of the shaft. The power is transmitted from the

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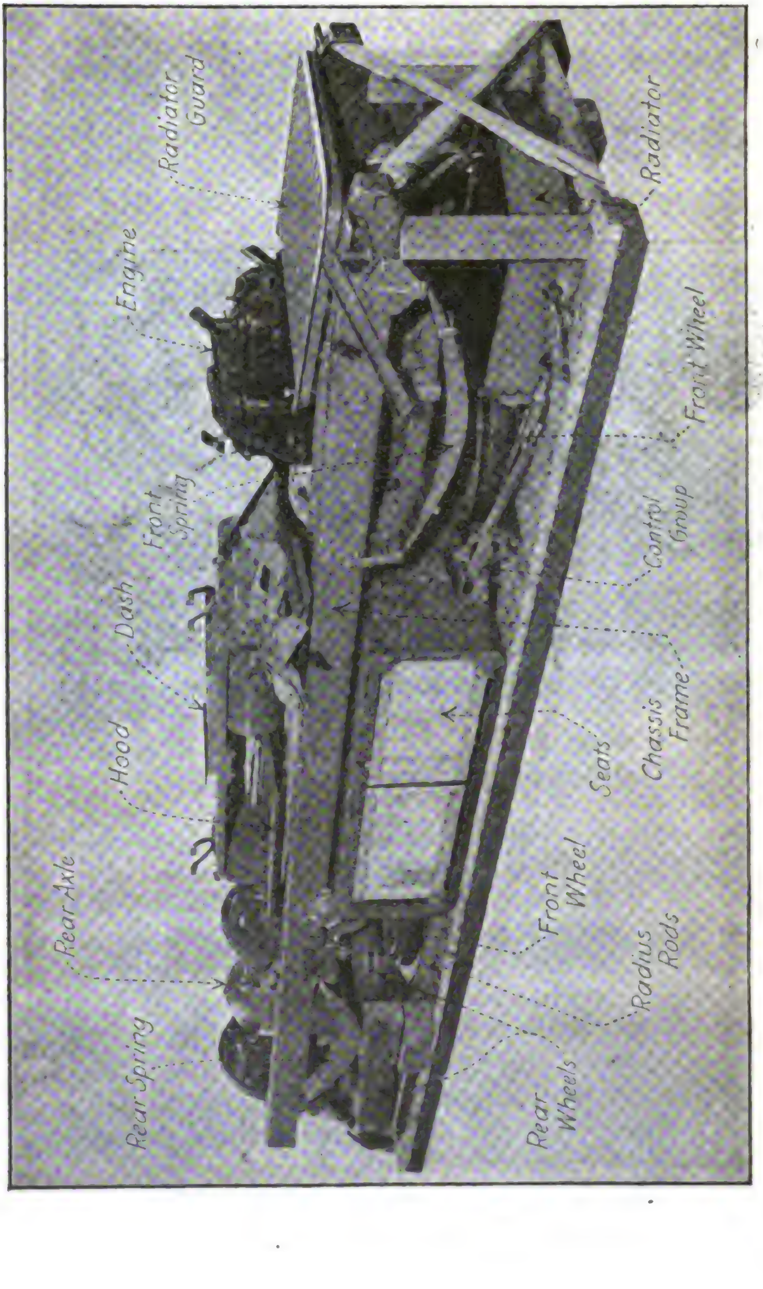
Radiator Guard
Engine
Front Spring
Dash
Hood
Rear Axle
Rear Spring
Radiator
Front Wheel
Control Group
Chassis Frame
Seats
Front Wheel
Radius Rods
Rear Wheels

Fig. 10.—Illustration Showing How Compactly the Standardized U. S. Army Air Service Truck May Be Packed When Dismantled and Ready for Shipment Over Seas.

rear universal joint through bevel gears to an M. & S. locking differential to the right and left jackshafts. On the end of each jackshaft there are pinions which engage with the internal gears attached to each rear wheel.

Instead of the bevel gearing shown at Diagram A, worm gearing may be used in the same manner, and in some double reduction axles, as shown at B, all gears may be carried close to the differential gear, the wheels being shaft driven.

Standard Truck Characteristics.—A study of the specifications of the motor trucks of American manufacture enables one to formulate with reasonable accuracy an average set of characteristics of design that will apply to the greater portion of the trucks in use. Considering, first, the matter of chassis weight, we find that a one-ton capacity truck will weigh about 3,500 pounds without the body. As we come to the trucks of greater capacity, the increase is by no means directly proportional to the augmented capacity. For example, a two-ton chassis will weigh about 4,000 pounds, which is but 500 pounds increase over that rated at one-half its normal capacity. The reason for this is not that the two-ton job is in any way slighted, but rather that most one-ton trucks are usually greatly overloaded, and are made to carry considerably more than their rated capacity by their owners. The weight of 3,000 pounds is a minimum that is essential to secure enduring mechanism, while that previously given is the average that seems desirable. A three-ton chassis will weigh 6,000 pounds, or as much as its rated capacity, but a three and a half-ton model will seldom weigh more than 6,500 pounds. A chassis rated at four-ton will tip the scales at 8,000 pounds, while one rated at five-ton will rarely exceed 8,500 pounds. A motor truck of the conventional two-wheel drive form carries from 60% to 85% of the weight on the rear of the traction wheels, the smaller percentage being found on the light trucks using modified passenger car chassis. Trucks of the four-wheel drive pattern generally have about 40% of the weight on the front wheels and 60% on the rear, this distribution being made because all wheels are employed for traction. The usual rear wheel drive truck carries 70% to 80% of the weight on the rear axle.

Motor Power Needed for Trucks.—The motor power required for trucks does not increase directly with capacity any more than chassis weight does, because the heavier trucks are geared lower

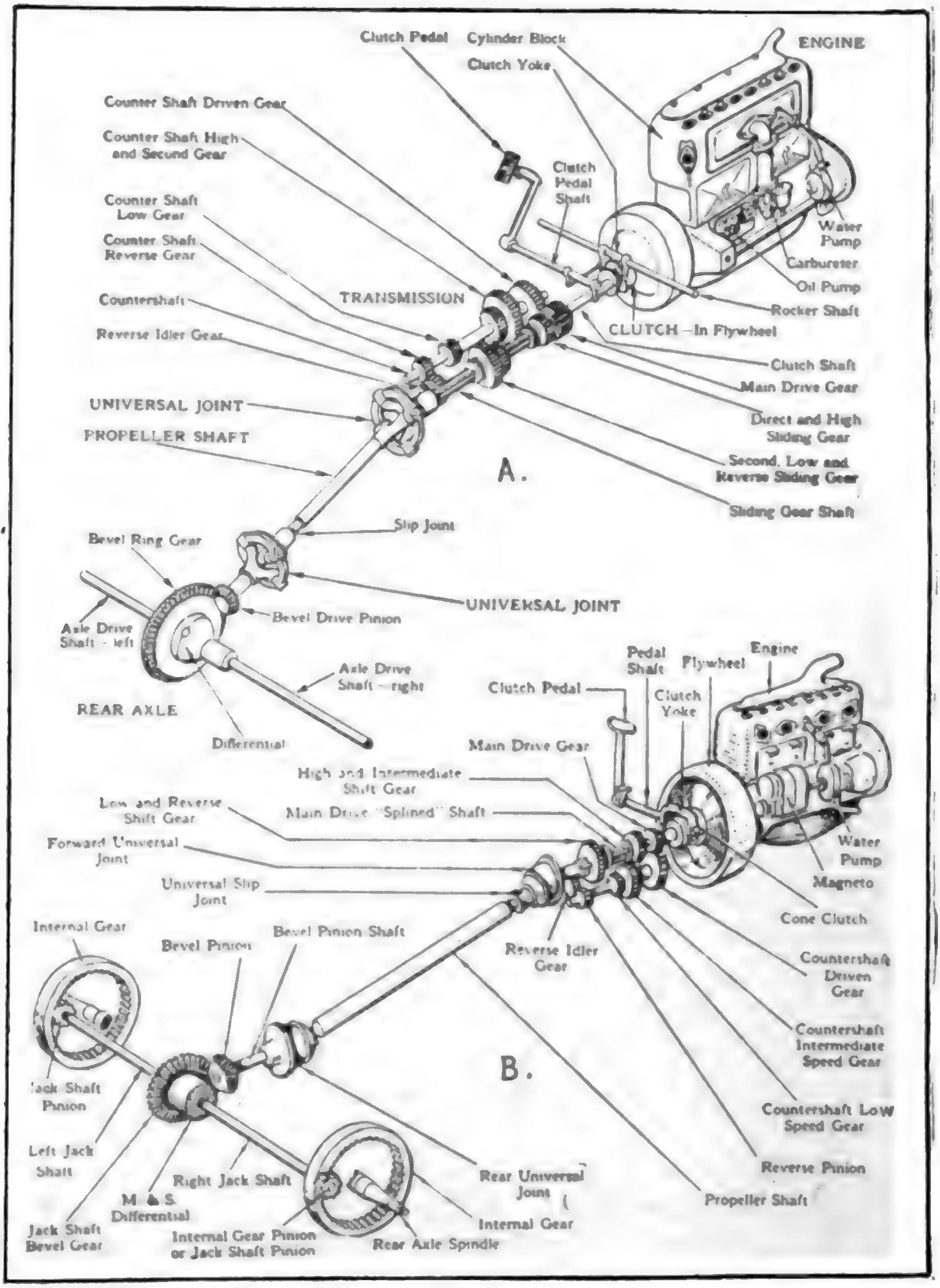
Clutch Pedal
Cylinder Block
Clutch Yoke
ENGINE
Counter Shaft Driven Gear
Counter Shaft High and Second Gear
Clutch Pedal Shaft
Counter Shaft Low Gear
Counter Shaft Reverse Gear
Water Pump
Carbureter
Oil Pump
Countershaft
TRANSMISSION
Rocker Shaft
Reverse Idler Gear
CLUTCH—In Flywheel
Clutch Shaft
Main Drive Gear
UNIVERSAL JOINT
Direct and High Sliding Gear
PROPELLER SHAFT
A.
Second, Low and Reverse Sliding Gear
Sliding Gear Shaft
Slip Joint
Bevel Ring Gear
UNIVERSAL JOINT
Axle Drive Shaft - left
Bevel Drive Pinion
Pedal Shaft
Flywheel
Engine
Axle Drive Shaft - right
Clutch Pedal
Clutch Yoke
REAR AXLE
Differential
Main Drive Gear
High and Intermediate Shift Gear
Low and Reverse Shift Gear
Main Drive "Splined" Shaft
Forward Universal Joint
Water Pump
Magneto
Universal Slip Joint
Cone Clutch
Internal Gear
Bevel Pinion
Bevel Pinion Shaft
Reverse Idler Gear
Countershaft Driven Gear
Countershaft Intermediate Speed Gear
B.
Jack Shaft Pinion
Countershaft Low Speed Gear
Left Jack Shaft
Reverse Pinion
Right Jack Shaft
Rear Universal Joint
M. & S. Differential
Propeller Shaft
Internal Gear
Jack Shaft Bevel Gear
Internal Gear Pinion or Jack Shaft Pinion
Rear Axle Spindle

Fig. 11.—Diagram Outlining Two Methods of Final Drive from Engine to Rear Wheels. At A, the Drive is by Bevel-Pinion and Ring Gear as in Passenger Car Practice. At B, Internal-Gear Drive is Shown. This is Becoming More Popular for Motor Truck Service.

and therefore do not call for the amount of power that is generally given the lighter and faster models. The power range is about as given in the following table:

MOTOR POWER FOR VARIOUS TRUCK CAPACITIES

Capacity in pounds	Motor horse power	H. P. per hundredweight
1,000	17	1.7
1,500	20	1.33
2,000	22	1.1
3,000	25	.8
4,000	28	.7
5,000	30	.7
6,000	31	.5
7,000	32	.4
8,000	32	.38
10,000	35	.35

It will be observed from the figures given above that the horse power per hundred pounds rated capacity becomes less as the truck increases in carrying ability. The reason more horsepower is used on the lighter trucks is that these are capable of greater speeds and are expected to have a better hill-climbing ability—i.e., they are expected to climb nearly all the hills a touring car will on the direct drive.

How Motor Truck Cost Varies.—Truck cost varies greatly and largely depends on the features of design of the individual truck and whether it is built by a quantity producer or by a firm building a relatively small number each year. As is true of touring car prices, the product of the quantity producers is materially less for a given capacity. It is possible by taking an average to give the truck cost in a unit figure per pound rated capacity. It is found that trucks rated at one-ton will cost from a minimum of 50 cents to a maximum of $1.00 per pound rated capacity. As an example of how low this cost may be, a distinctive design of one-ton capacity trucks sells for as little as 25 cents per pound rated capacity, this bringing the cost of the truck chassis to about $500. Most trucks are of heavier construction than this model, so the figures previously given may be considered representative. There is little difference in the cost of a one and one-half or two-ton truck, which will average about 75 cents per pound. Three-ton trucks sell for from 50 cents to 66⅔ cents per pound. Four-ton trucks will range from that figure to 75 cents per pound. A good five-ton truck can

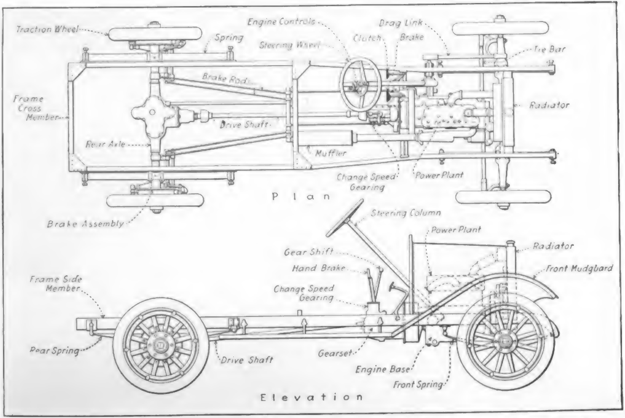
Traction Wheel
Spring
Engine Controls
Steering Wheel
Drag Link
Clutch
Brake
Tie Bar
Frame Cross Member
Brake Rod
Radiator
Drive Shaft
Rear Axle
Muffler
Change Speed Gearing
Power Plant
Plan
Brake Assembly
Steering Column
Power Plant
Radiator
Gear Shift
Hand Brake
Front Mudguard
Frame Side Member
Change Speed Gearing
Rear Spring
Drive Shaft
Gearset
Engine Base
Front Spring
Elevation

Fig. 12.—Plan and Side Elevation of Light Truck for 1,500-Pound Load Shows Modern Trend.

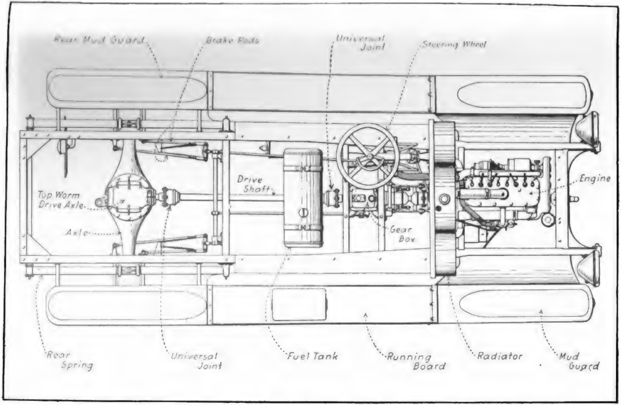
Rear Mud Guard
Brake Rods
Universal Joint
Steering Wheel
Engine
Top Worm Drive Axle
Axle
Drive Shaft
Gear Box
Rear Spring
Universal Joint
Fuel Tank
Running Board
Radiator
Mud Guard

Fig. 13.—Plan View of Typical Light Truck with Worm-Drive Axle Showing Power Plant Installation.

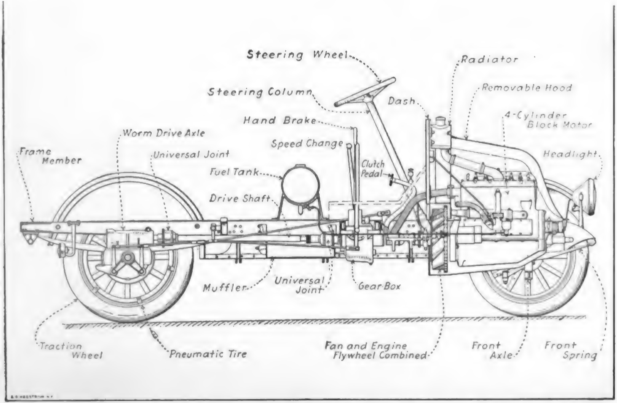
Steering Wheel
Radiator
Steering Column
Dash
Removable Hood
4-Cylinder Block Motor
Hand Brake
Worm Drive Axle
Speed Change
Frame Member
Universal Joint
Clutch Pedal
Headlight
Fuel Tank
Drive Shaft
Muffler
Universal Joint
Gear Box
Traction Wheel
Pneumatic Tire
Fan and Engine Flywheel Combined
Front Axle
Front Spring

Fig. 14.—Side Elevation of Typical Light Truck Showing Power Plant and Transmission Installation to Secure Straight Line Shaft Drive to Worm-Gear-Driven Rear Axle.

be purchased for 50 cents per pound rated capacity. The heaviest truck manufactured as a standard product, which is rated as seven and one-half ton capacity, costs approximately 33⅓ cents per pound. The figures given apply only to the chassis in all cases, except the one-ton classification, which includes the bodies in the cost estimate.

Typical Truck Designs.—One would naturally expect motor truck designs to vary greatly an account of the diversity of opinion relative to motor truck engineering matters which now obtain in this industry. Various designers have a preference for certain methods of construction which have proven themselves to be entirely satisfactory on their product which are not favored to the same extent on other trucks of similar capacity. As previously mentioned, the placing of the various units determines truck chassis design to a certain extent. The truck shown at Fig. 15 is a modification of the practice ordinarily followed by passenger-carrying car designers. The engine and gear box are of unit form and shaft drive transmits the power to a bevel gear axle of the usual pattern. The motor is rated at 14.4 horse power and has cylinders cast in block with a detachable cylinder head. The bore of the cylinder is three inches and the piston stroke four and one-half inches. A pressed steel frame supported by semi-elliptic front and rear springs is used. The change speed gearing provides three forward speeds and a cone clutch is utilized to connect the engine power to the gearset. The tires are 31 x 4 inch pneumatic, and the car has a wheel base of 108 inches. It is usually equipped with a light van or screen side parcel delivery body.

The truck shown at Fig. 16 carries 1,500 pounds and is a modification of a popular touring car that is built in large quantities. In this design, the power plant and clutch form a unit that is distinct from the change speed gearing. This truck employs an electric starting and lighting system just as the touring car of the same make does. The motor is rated at 27.2 horse power and has cylinders cast in pairs. The bore is 4⅛ inches and the stroke 5½ inches. A multiple disc clutch and three speed gearsets transmit the power through a double universal joint drive shaft to a bevel gear drive rear axle. The car has a 128 inch wheel base, the wooden wheels are provided with 34 inch x 4½ inch pneumatic tires fitted to demountable rims all around. A pressed steel frame is employed and as is usual in motor truck

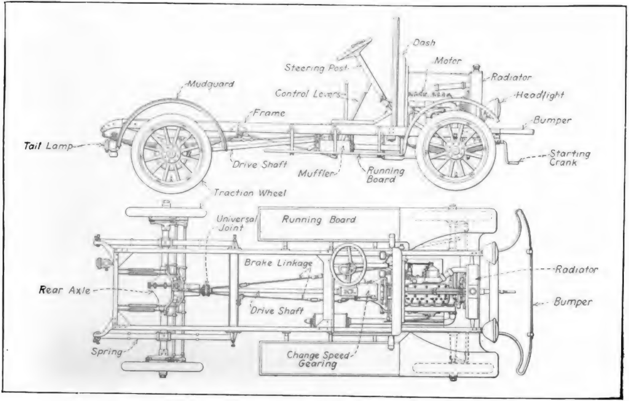
Dash
Steering Post
Motor
Radiator
Mudguard
Control Levers
Headlight
Frame
Bumper
Tail Lamp
Starting Crank
Drive Shaft
Muffler
Running Board
Traction Wheel
Universal Joint
Running Board
Brake Linkage
Radiator
Rear Axle
Drive Shaft
Bumper
Spring
Change Speed Gearing

Fig. 15.—Plan and Side Elevation of the Vim Model 21 One-Half-Ton Truck.

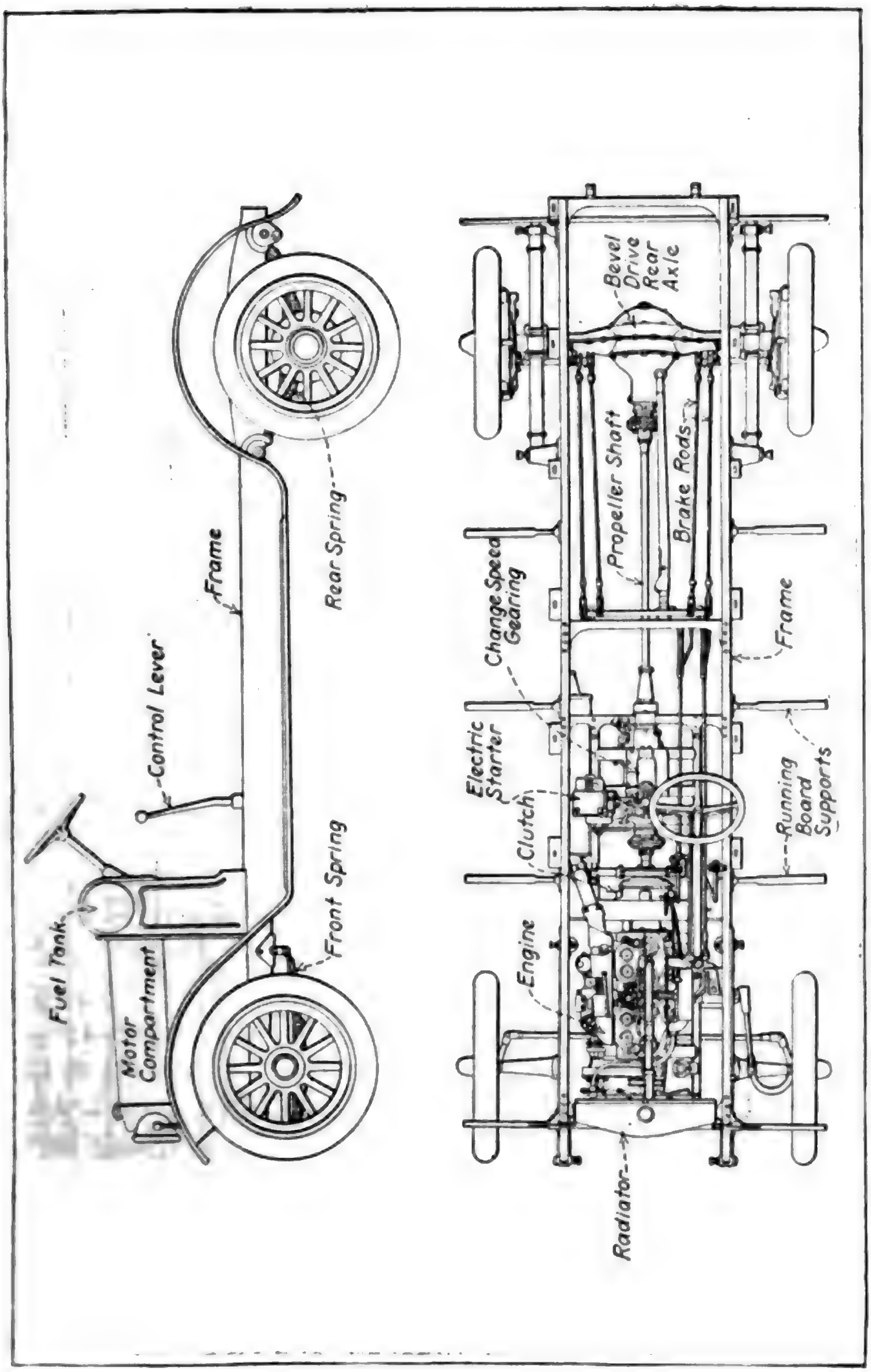
Fuel Tank
Motor Compartment
Control Lever
Frame
Front Spring
Rear Spring
Radiator
Engine
Clutch
Electric Starter
Change Speed Gearing
Propeller Shaft
Bevel Drive Rear Axle
Brake Rods
Frame
Running Board Supports

Fig. 16.—Side and Plan Views of the Reo Model F Three-Quarter-Ton Truck which is Known as the "Speed Wagon."

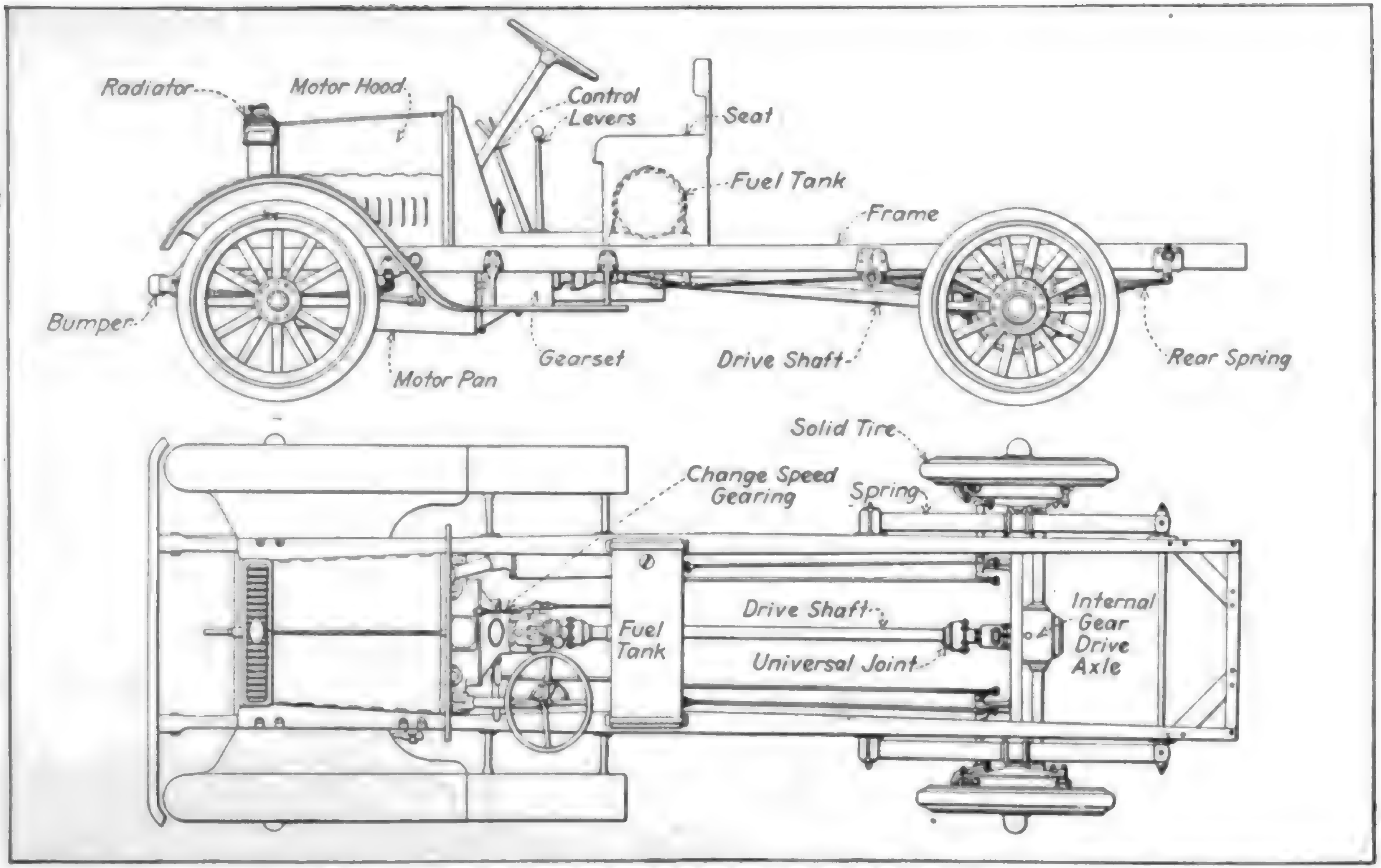
Radiator
Motor Hood
Control Levers
Seat
Fuel Tank
Frame
Bumper
Motor Pan
Gearset
Drive Shaft
Rear Spring
Solid Tire
Change Speed Gearing
Spring
Drive Shaft
Fuel Tank
Universal Joint
Internal Gear Drive Axle

Fig. 17.—Side Elevation and Plan View of Commerce Model E One-Ton Truck.

construction semi-elliptic springs are used both front and rear. Owing to the powerful motor, this model is known as the "Speed Wagon."

While both of the models previously shown are really modifications of passenger car practice, the one-ton truck depicted at Fig. 17 is representative of light truck design in which a departure is made from the passenger-carrying types. A unit power plant is employed, the drive from a cone clutch and three speed gear box is through a long double universal joint drive shaft to a rear axle of the double reduction or internal gear drive form. The motor is rated at 22.5 horse power and is a four-cylinder type having a bore of 3¾ inches and stroke of 5 inches. The chassis length is 186 inches. Its weight is 2,500 pounds and the truck has a 126 inch wheel base. Artillery wooden wheels, provided with 34 inch x 4 inch solid rubber tires, are used. Three changes of speed are provided, the low gear permitting a maximum of nine miles per hour, the second speed sixteen miles and the high gear or direct drive a maximum of thirty miles per hour.

The 1½-ton motor truck shown at Fig. 18 is a distinctive design employing the four wheel drive principle. The motor is rated at 19.6 horse power and has a bore of 3½ inches and a stroke of six inches. A multiple disc clutch, mounted as a unit with the power plant, delivers the engine power to a three speed gear box, which is mounted about in the center of the frame. A special form of change speed gearing is required owing to the four wheel drive principle, because double universally jointed driving shafts must extend from the front and rear to the internal gear drive axles. A rolled steel frame built up of standard structural shapes is used. Steering is by the front wheels only in this truck, though some of the four wheel drive types combine directive and tractive functions at all four wheels. Steel wheels shod with 32 inch x 4 inch solid rubber tires support the chassis. The weight is 3,300 pounds. The gear ratios in the change speed gearing are such that a low speed of six miles per hour, a second speed of 10.6 and a high speed of eighteen miles are obtained.

The two-ton truck outlined at Fig. 19 is a distinctive pattern and is the only one now on the American market employing a two-cylinder engine as motive power. This power plant is rated at eighteen horse power and has cylinders 4¾ inches bore and 4½ inches stroke. It is located under the driver's seat, which is

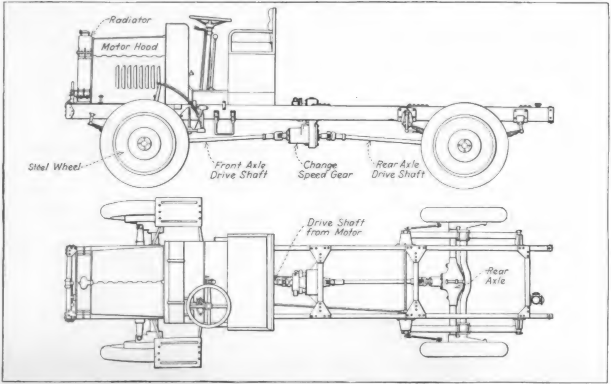
Radiator
Motor Hood
Steel Wheel
Front Axle Drive Shaft
Change Speed Gear
Rear Axle Drive Shaft
Drive Shaft from Motor
Rear Axle

Fig. 18.—Side Elevation and Plan View of the Winther One-and-One-Half-Ton Truck, Which Embodies the Four-Wheel Drive Principle.

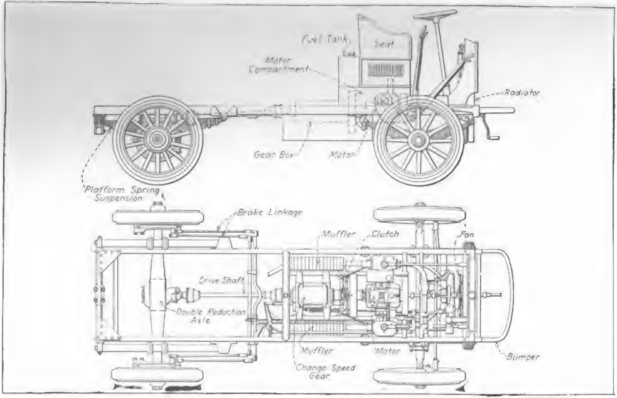
Fuel Tank
Seat
Motor Compartment
Radiator
Gear Box
Motor
Platform Spring Suspension
Brake Linkage
Muffler
Clutch
Fan
Drive Shaft
Double Reduction Axle
Muffler
Motor
Change Speed Gear
Bumper

Fig. 19.—Side Elevation and Plan View of Auto Car Model XXI-F Two-Ton Truck Which Uses Double Opposed Horizontal Engine for Power.

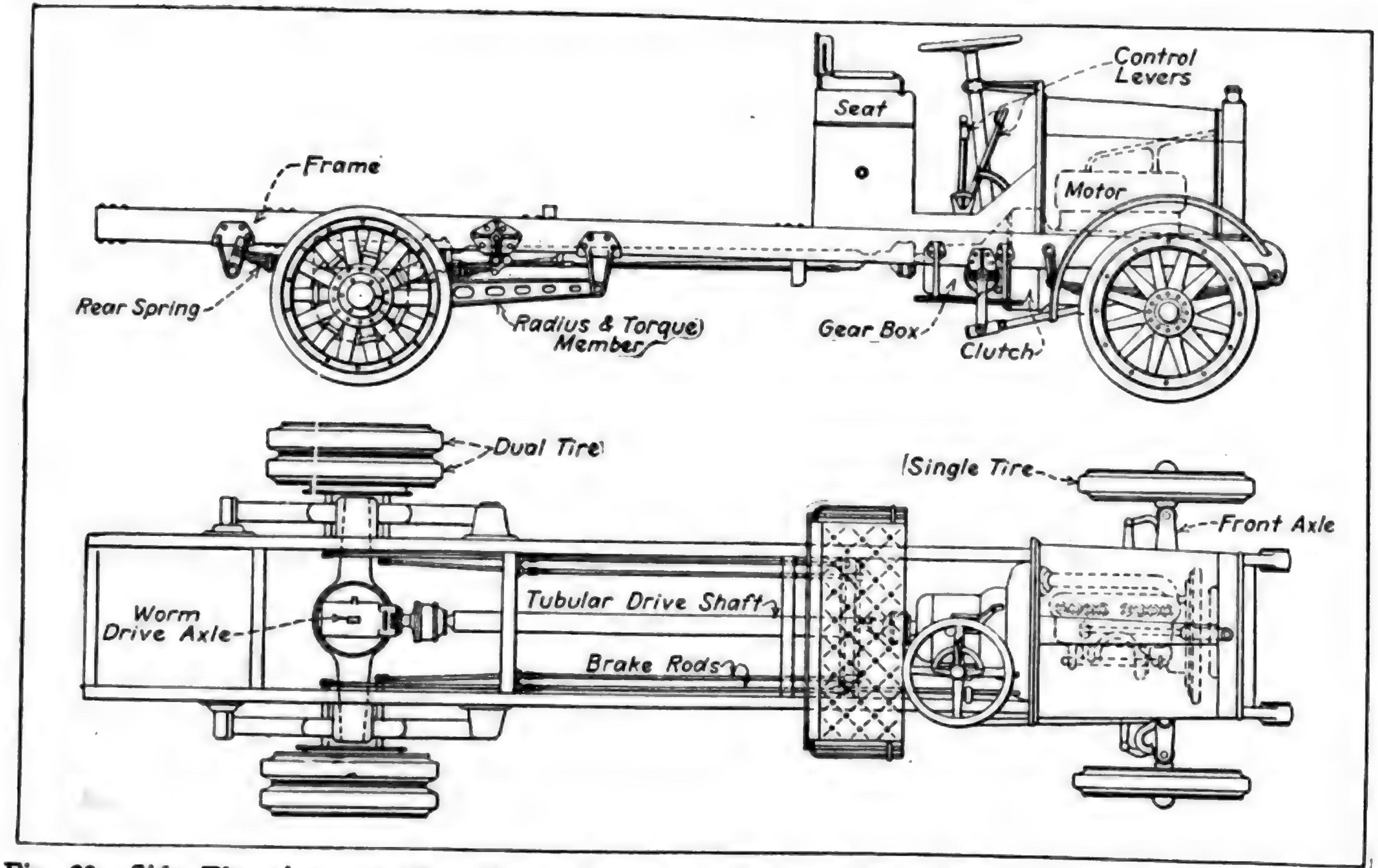
Control Levers
Seat
Frame
Motor
Rear Spring
Radius & Torque Member
Gear Box
Clutch
Dual Tire
Single Tire
Front Axle
Worm Drive Axle
Tubular Drive Shaft
Brake Rods

Fig. 20.—Side Elevation and Plan View of the Selden Model M. L. Three-and-One-Half-Ton Truck Which Uses a Unit Power Plant and Long Tubular Drive Shaft.

mounted on hinges so it can be tilted forward to give ready access to the engine. A three plate clutch and three speed gear box are used. The double reduction rear axle is a special design having combined spur and bevel gear drive. The frame is of pressed steel and while semi-elliptic springs are used in front a platform spring suspension supports the rear. Owing to the location of the motor and its compactness, a very short wheel base of ninety-seven inches can be used without any sacrifice of body length or capacity. This short wheel base makes it very easy to handle the truck in congested traffic, as it requires considerably less space to maneuver it in than the conventional longer wheel base trucks need. The front tires are 34 inch x 4 inch solid rubber and the rear are 34 inch x 5 inch of the same type.

The 3½-ton capacity truck chassis shown at Fig. 20 is a good example of that method of construction that employs a unit power plant and a long tubular drive shaft. The engine is a four-cylinder form, rated at 32.5 horse power and having cylinders of 4½ inch bore by 5½ inch stroke. The clutch is a multiple disc pattern and in connection with the four speed gear box it is an integral unit with the engine crankcase. The final drive is by a worm gear axle. The frame is a pressed steel pattern. Substantial radius rods are provided to take driving and braking torque reaction so that the rear springs are called upon only to carry the load and not to function as torque members, as is necessary when the Hotchkiss drive is employed. The wheel base is 164 inches. Wooden wheels are used, the front being equipped with 36 x 5-inch single solid tires and the rear with 36 x 5-inch dual tires. The weight is given as 6,550 pounds. The speeds provided are 3.3 miles on low gear, 5 miles on the second speed, 9 miles on the third speed, and 13 miles per hour on the high speed.

The 3½-ton truck shown at Fig. 21 is somewhat different than that previously described, because the change speed gearing is placed as an independent unit at about a central point in the frame instead of being incorporated with the engine unit. Instead of using one long driving shaft, as in the design at Fig. 20, two shorter drive shafts are utilized, one leading from the clutch case to the front end of the gear box, the other extending from the rear end of the gear box to the worm drive axle. The engine in this truck is rated at 29 horse power and is 4¼ inches

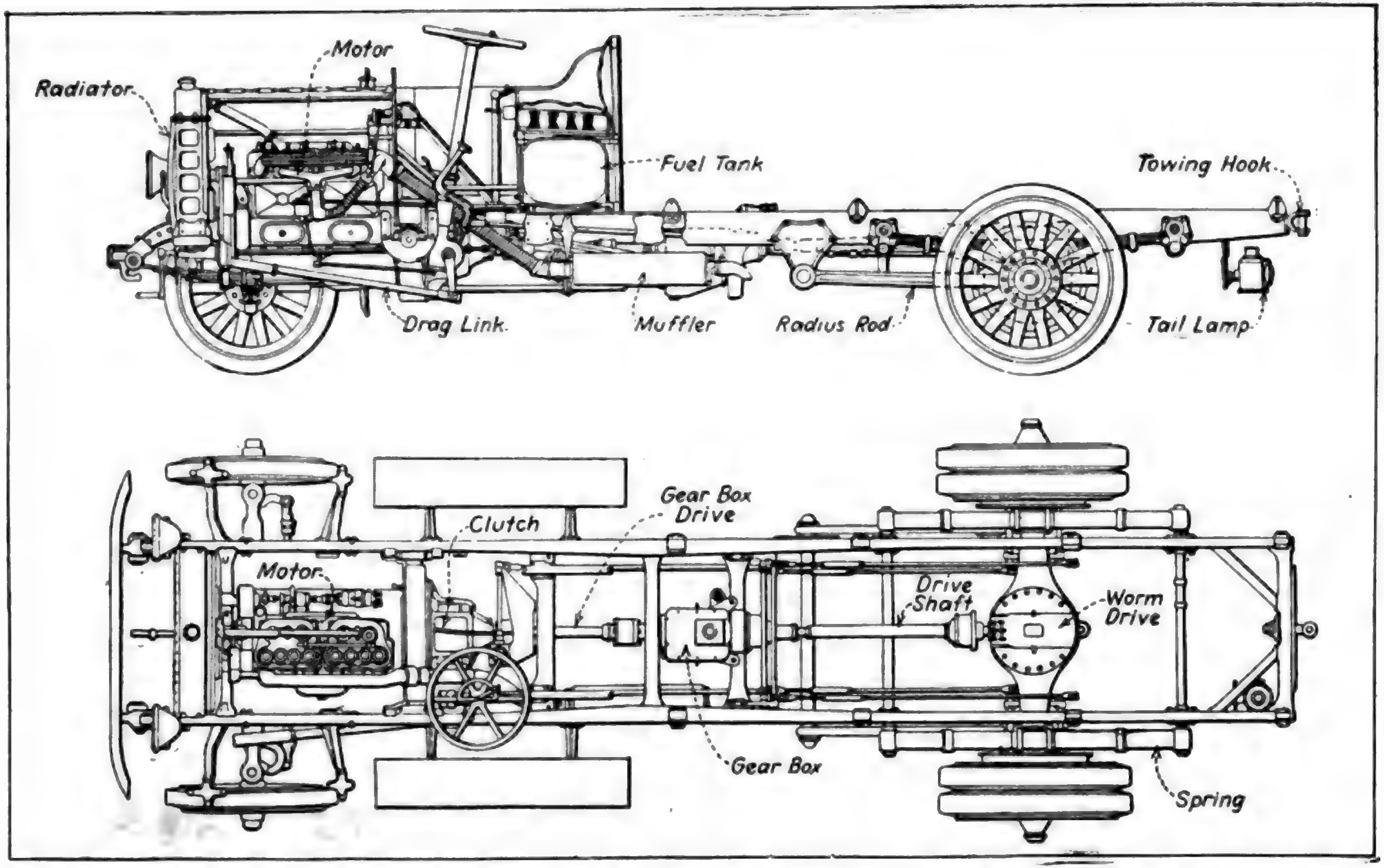
Radiator
Motor
Fuel Tank
Towing Hook
Drag Link
Muffler
Radius Rod
Tail Lamp
Clutch
Gear Box Drive
Motor
Drive Shaft
Worm Drive
Gear Box
Spring

Fig. 21.—Side Elevation and Plan View of the Sterling Three-and-One-Half-Ton Truck Which has a Gearbox Located Amidships and Which Uses Two-Drive Shafts to Transmit the Power.

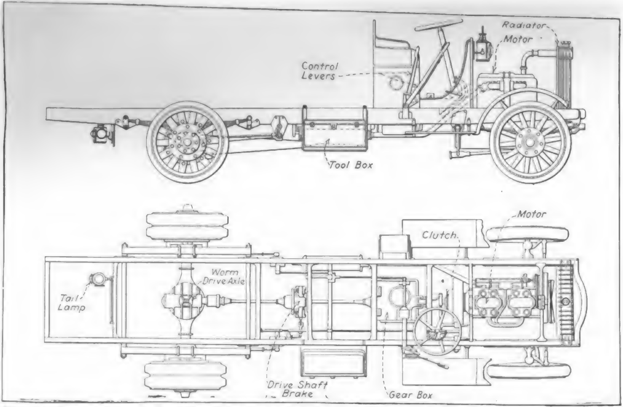
Radiator
Motor
Control Levers
Tool Box
Motor
Clutch
Worm Drive Axle
Tail Lamp
Drive Shaft Brake
Gear Box

Fig. 22.—Riker Model B B Four-Ton Truck is Representative of Standard Design for Trucks of Large Capacity.

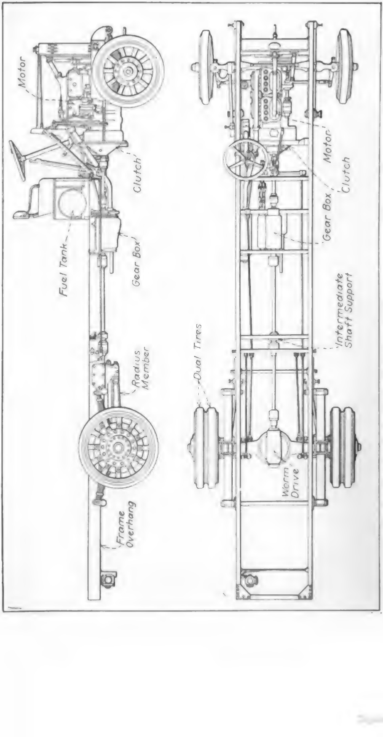
Motor
Clutch
Fuel Tank
Gear Box
Radius Member
Frame Overhang
Dual Tires
Worm Drive
Intermediate Shaft Support
Motor
Clutch
Gear Box

Fig. 23.—Side Elevation and Plan View of the G. M. C. Model 101-B Five-Ton Truck.

bore by 5½ stroke. The clutch is a multiple disc type and the change speed gearing operates on the individual clutch system in which all gears are in mesh at all times instead of the usual sliding gear construction. The frame is of pressed steel, and a wheel base of 162 inches is used. The front wheels are provided with 36 x 5-inch single solid tires, the rear wheels with 40 x 5-inch dual tires. The weight of the chassis is given as 8,300 pounds. The speeds provided by the gear box and drive axle reduction are 2.9 miles on the slow speed, 7.2 miles on the second speed, and 13 miles on the third speed or direct drive.

The truck chassis, outlined at Fig. 22, is a good example of the construction followed in trucks of that capacity. The four-speed gear box is placed almost immediately back of the engine, but is mounted as an independent unit. The drive from the gear box to the rear axle is by two drive shafts instead of one long member. The engine is rated at 29.9 horse power and has the cylinders cast in pairs. The bore is 4¼ inches and the stroke 6 inches. A cone clutch is interposed between the engine and four-speed gear box. A pressed steel frame is used. The wheel base is 150 inches, the tires are 36 x 5-inch solid front, and 36 x 6-inch dual solid on the rear. The weight of the chassis is given at 7,100 pounds. The speeds possible are 3.4 miles per hour on the low gear, 5.95 miles on the second speed, 8.75 miles on the third speed and 14.5 miles on the fourth speed.

A 5-ton truck of good design is shown at Fig. 23. As is usual in construction, the motor and clutch are one unit while the gear box is an entirely independent member carried by a subframe. A short, driving shaft transmits the engine power from the clutch to the front end of the gear box. Owing to the length of the frame the drive from the gear box to the worm gear axle is through two short shafts and three universal joints. The motor is 32.5 horse power. The cylinders are cast in pairs and are 4½ inches bore and 5½ inches stroke. The clutch is a multiple disc type. The change speed gearing gives four forward speeds and one reverse. The frame is built up of rolled steel structural shapes. The wheel base is 163 inches. The front wheels are provided with 36 x 6-inch single solid tires and 40 x 6-inch dual solid tires are installed on the rear wheels. The chassis weight is given as 8,000 pounds, and a possible speed of 10 miles per hour is obtained on the high gear.

A 5-ton truck of radically different design from that previously

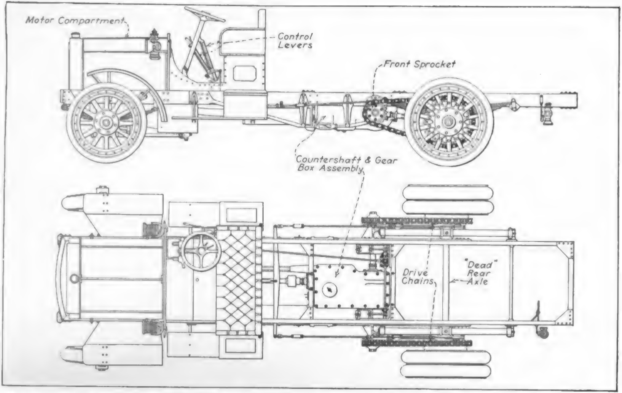
Motor Compartment
Control Levers
Front Sprocket
Countershaft & Gear Box Assembly
Drive Chains
"Dead" Rear Axle

Fig. 24.—Side Elevation and Plan View of the Peerless Model T. C. Five-Ton Truck Showing Final Drive System in Which Side Chains are Used.

described is shown at Fig. 24. In this the final drive to the rear wheels is by chain and sprockets instead of by the usual shaft and gearing in the rear axle. The motor, which is rated at 32.5 horse power, is mounted at the front end of the rolled steel frame. A cone clutch is installed as a unit with the motor, this transmitting power by a shaft to a four-speed gear box which is mounted as a unit with the countershaft construction. The primary drive from the change speed gearing is to bevel gears which turn a differential assembly from which the shafts project to the sides of the frame. the shaft ends carrying the small driving sprockets. The rear wheels are driven by large sprockets securely bolted to the spokes, and are turned by the countershaft through the medium of heavy roller chains. The engine bore is 4½ inches and the stroke is 6½ inches. The truck has 151 inches wheel base. The front wheels are provided with 36 x 6-inch single tires and the rear with 40 x 6-inch dual solid tires.

A very successful type of 5½-ton truck is shown at Fig. 25. In this design the power plant is mounted ahead of the radiator instead of behind it, as is the usual practice. The motor is rated at 40 horse power and has cylinders 5 inches bore and 6 inches stroke. The power is transmitted through a plate clutch to a three-speed gear box by means of a double universally jointed drive shaft. The gear box is incorporated with the countershaft following the usual design practice for double side chain drive. Two sets of brakes are provided, one set acting on drums fastened to the sprockets at the countershaft end, while the other set acts on the brake drum of the rear axle. The advantage claimed for the chain drive construction is that a very much lighter rear axle can be used which reduces the amount of unsprung weight, and in addition the power is applied close to the rim of the wheel or the point of contact of the rear tire and the ground. This advantage is shared by the internal gear drive form of rear axles, but these members must be heavier than the simple dead axle form used with chain drive. The wheel base of the truck is 180 inches. The front wheels have 36 x 6-inch single solid tires, the rear wheels 40 x 6-inch dual tires.

Body Weight Allowances.—Any motor truck is composed of two assemblies: the chassis, which is the name given to the entire mechanism, and the body, which is that part of the truck in

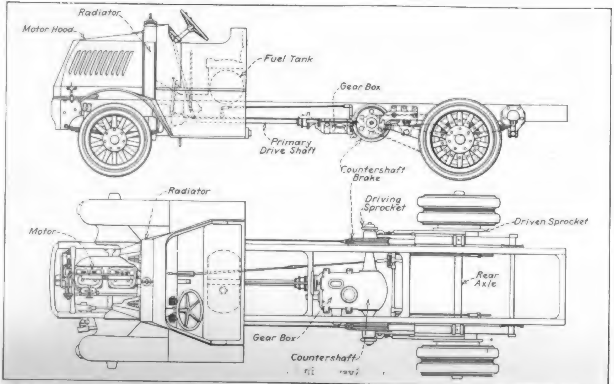
Radiator
Motor Hood
Fuel Tank
Gear Box
Primary Drive Shaft
Countershaft Brake
Radiator
Driving Sprocket
Driven Sprocket
Motor
Rear Axle
Gear Box
Countershaft

Fig. 25.—Side Elevation and Plan Views of the Mack Model A. C. Five-and-One-Half-Ton Truck Showing Location of Radiator Back of Engine and Drive to Rear Wheels by Side Chains.

which the load is placed. Any structure distinct from the chassis, whether it is a framework, platform, or box type, may be considered as the truck body. Inasmuch as the motor truck has been adapted to a wide variety of industrial uses, one can expect that a great variety of body structures have been developed, each of the types being thought best suited for the work it is to perform. Bodies may be of relatively simple construction or, at the other hand, may be quite complicated, such as the refrigerator types used for hauling perishable products.

Steel bodies of standard forms are now making their appearance for contractor's use, and some of the quantity producers of light trucks use sheet steel extensively in the construction of all their bodies. The usual form is a composite structure built up of wood and metal. The former material is just as widely used for motor truck bodies as it was for horse-drawn wagons. When a special body design is called for it can be executed more economically and quicker in wood than in any other material. Combination bodies, to be described in proper sequence, offer advantages that are valuable because by the removal or addition of easily handled structural parts the owner is enabled to have bodies suitable for different work at short notice.

The important point to consider in body construction is to secure strength without having excessive weight, because there are certain well-defined limits beyond which it is not desirable to go. An excessively heavy body will reduce the total carrying capacity of the truck by the amount of weight that may be considered surplus. One of the large motor truck manufacturers allows the following maximum weights for various carrying capacity trucks:

Capacity of Truck in pounds	Maximum Weight-body permissible
2,000	1,000
3,000	1,250
4,000	1,500
6,000	2,000
9,000	2,250
10,000	2,500

The following table of body weight allowances is that adopted by the National Automobile Chamber of Commerce, and the weights given apply to both electric trucks and those propelled by internal combustion motors:

BODY WEIGHT ALLOWANCES

Capacity of Vehicle in tons	Body Weight Allowance in pounds	Capacity of Vehicle in tons	Body Weight Allowance in pounds
½	600	4½	1,750
1	900	5	1,800
1½	1,050	6	1,900
2	1,200	7	2,000
2½	1,350	8	2,100
3	1,500	9	2,200
3½	1,600	10	2,300
4	1,700		

The wood generally used in truck body construction is oak or ash, because of its strength, and the floors are often reinforced by a series of metal strips. Fore-and-aft sub-sills are fastened to the top of the chassis frame members, to form the foundation for the cross members which are called bolsters and to which the floor planking is attached. The number of bolsters used varies according to the load to be carried and the length of the frame. In all cases the bolsters are attached to the fore-and-aft sills by bracing irons just as used in ordinary wagon construction. Naturally, the motor truck platform varies with the capacity of the vehicle. A platform for a one-ton truck will vary from 64 to 70 inches wide and from 90 to 100 inches long. The larger bodies such as used on a five- or six-ton chassis may be 90 inches wide and over 200 inches long. Floor traps must be provided in the platform to give access to the transmission and rear axles, and these removable sections must be designed so they may be handled without too much trouble to insure that inspection of the units of the chassis mechanism beneath the body will not be neglected.

Though motor truck wagon work may exist in a large number of designs, all of these may be divided into one of four main classifications. These are stationary, which includes all rack, platform, express and van body types. The movable bodies include special elevating and dumping designs. Demountable bodies are those forms in which portions may be easily removed without disturbing the main sills or platform, such removable bodies carrying the load and being of such a design that they can be replaced with others of similar pattern that are not loaded. All other forms may be grouped in a special body classification.

Body Builders' Dimensions.—Body builders must have certain dimensions to work with in order to fit any specific chassis. For this reason all of the leading truck manufacturers furnish what is known as body builders' drawings and specifications. A typical set, such as furnished by the Four-Wheel-Drive truck makers for their three-ton truck, is shown at Fig. 26 with the principal dimensions.

BODY BUILDERS' DIMENSIONS

F. W. D. TRUCK

	3-Ton Truck	Standard inches	Long Wheel Base inches
	Wheel Base	124	156
	Frame Length	200	248
	Overall of Car	215	263
	Tread	56	56
A	Back of Seat	136	184
B	Over Floor Trap	60	60
C	To Floor Trap	8¼	8¼
D	Clearance Back of Seat	6	6
E	Rear Wheels to End of Frame	39	55
F	Front Wheels to End of Frame	37	37
G	Clearance under Transmission	15	15
H	Clearance under the Rear Axle Housing	9 11/16	9 11/16
J	Depth of Frame	5⅛	5⅛
K	Depth of Subsill	5	5
L	Depth of Cross Stringer	2¼	2¼
M	Tires	36	36
N	Height of Frame at Rear (Loaded)	37	37
N	Height of Frame at Rear (Unloaded)	39	39
O	Height over Seat (Loaded)	81	81
O	Height over Seat (Unloaded)	82	82
P	Top of Seat to Top of Frame	44½	44½
Q	Top of Dash to Top of Frame	37⅛	37⅛
R	Top of Radiator to Top of Frame	31⅜	31⅜
S	Front of Radiator to Dash	14¼	14¼
T	Dash to Front of Seat	19¾	19¾
U	Depth of Seat	18¾	18¾
V	Back of Seat over Tank Bracket	15¼	15¼
W	Diameter of Tank	12⅜	12⅜
X	Back of Seat Frame over Tank Bracket	2¾	2¾
Y	Overall Width of Seat	43¾	43¾
Z	Overall Length of Tank	42	42

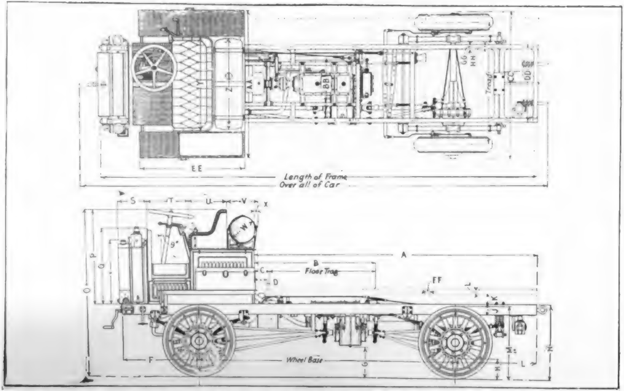
Tread
GG
HH
CC
DD
AA
BB
Y
Z
I
EE
Length of Frame
Over all of Car
S
T
U
V
X
W
9°
A
B
Floor Trag
C
D
FF
J
K
L
M
N
O
P
Q
F
G
H
Wheel Base

Fig. 26.—Side Elevation and Plan View of the Four-Wheel-Drive Truck Giving Principal Dimensions Supplied to Body Makers.

	3-Ton Truck	Standard inches	Long Wheel Base inches
AA	Width over Running Boards....	68	68
BB	Width Trap	24	24
CC	Width over Hubs	70½	70½
DD	Width Frame	36	36
EE	Length of Running Boards......	48	48
FF	Thickness Cross Stringer	2	2
GG	Thickness Subsill	2½	2½
HH	Thickness Frame	2	2

The standard Packard truck body with removable slatted racks and gate is shown at Fig. 27, and the dimensions of this type body for the various capacity chassis produced by this maker may be readily ascertained from the accompanying table.

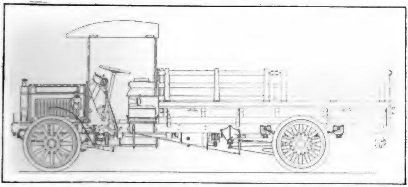

Fig. 27.—The Packard Standard Slatted Removable Gate Body.

Open Body Forms.—Through the courtesy of the Locomobile Company, who build the Riker truck, it is possible to present a wide variety of body designs that are available to purchasers of these trucks. The platform body shown at Fig. 28, A, is the simplest possible form. It has a length of 12 to 15 feet and is 6 feet 6 inches wide. This is suitable for carrying lumber, cord wood, marble and cut stone, mason's supplies, shingles, baled hay, sheet steel, expanded metal and goods in boxes or large crates. It can also be employed to advantage for heavy timbers, contractor's skips, machinery, safes, and for the use of nurseries in handling trees. The body shown at B, Fig. 28, is similar to that shown above, but has stakes added to it which may be long or short and with or without chains, as desired. By the removal of the side and end stakes the plain platform type body is obtained. The driver's cab with curtains may be fitted with any form body of the open type, as it is a detachable

DIMENSIONS STANDARD PACKARD BODY NO. 138

LENGTHS	2—2½ Ton Truck Standard Chassis 12 foot Wheel Base	2—2½ Ton Truck Standard Chassis 14 foot Wheel Base	3—3½ Ton or 4—4½ Ton Truck Standard Chassis 13 foot Wheel Base	3—3½ Ton or 4—4½ Ton Truck Standard Chassis 15 foot 6 inch Wheel Base	5—5½ Ton or 6—6½ Ton Truck Standard Chassis 13 foot Wheel Base	5—5½ Ton or 6—6½ Ton Truck Standard Chassis 15 foot 6 inch Wheel Base
Minimum—						
Body, clear	8' 8½"	12' 1½"	9' 7½"	13' 1½"	9' 10½"	13' 1½"
Body, over all	9' 1"	12' 6"	10' 0"	13' 6"	10' 3"	13' 6"
Truck, over all	16' 7½"	20' ½"	17' 10½"	21' 4½"	18' 1½"	21' 4½"
Standard—						
Body, clear	10' 7½"	13' 7½"	11' 7½"	15' 7½"	11' 7½"	15' 7½"
Body, over all	11' 0"	14' 0"	12' 0"	16' 0"	12' 0"	16' 0"
Truck, over all	18' 6½"	21' 6½"	19' 10½"	23' 10½"	19' 10½"	23' 10½"
Maximum—						
Body, clear	12' 1½"	15' 7½"	13' 1½"	18' 1½"	13' 1½"	18' 1½"
Body, over all	12' 6"	16' 0"	13' 6"	18' 6"	13' 6"	18' 6"
Truck, over all	20' ½"	23' 6½"	21' 4½"	26'. 4½"	21' 4½"	26' 4½"
HEIGHTS, without load		2—2½ Ton	3—3½ Ton	4—4½ Ton	5—5½ Ton	6—6½ Ton
Truck, over all		5' 7½"	5' 10¼"	6' 1"	6' 2"	6' 2"
Truck, with 8200 top		7' 10¾"	8' 2¼"	8' 3¾"	8' 6½"	8' 6½"
Body, floor at rear		3' 6⅞"	3' 9¼"	4' 1"	4' 2"	4' 2"
WIDTHS		2—2½ Ton	3—3½ Ton	4—4½ Ton	5—5½ Ton	6—6½ Ton
Chassis, over all		6' 2⅜"	7' 4"	7' 4"	7' 4⅜"	7' 4⅜"
Body, over all		5' 7⅜"	6' 7⅜"	6' 7⅜"	7' 4½"	7' 4½"
Body, clear		5' 0"	6' 0"	6' 0"	6' 9"	6' 9"

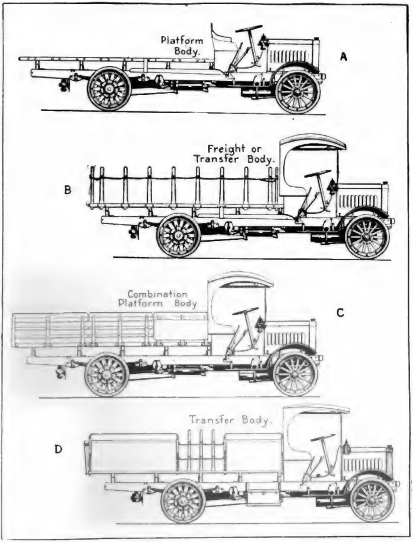
Platform Body.
A
Freight or Transfer Body.
B
Combination Platform Body
C
Transfer Body.
D

Fig. 28.—Diagram Showing a Variety of Motor Truck Bodies Suited for Freight or Transfer Duty.

unit. The length of the body shown is 12 feet 9 inches; its width is 6 feet and height of the stakes 2 feet 6 inches.

The combination platform body, shown at C, is suitable for practically all of the work the two previously described are except the handling of lumber, marble and cut stone. It is well suited for all boxed or barreled material and bottled or chemical goods in cases, and for general contracting. It may be had

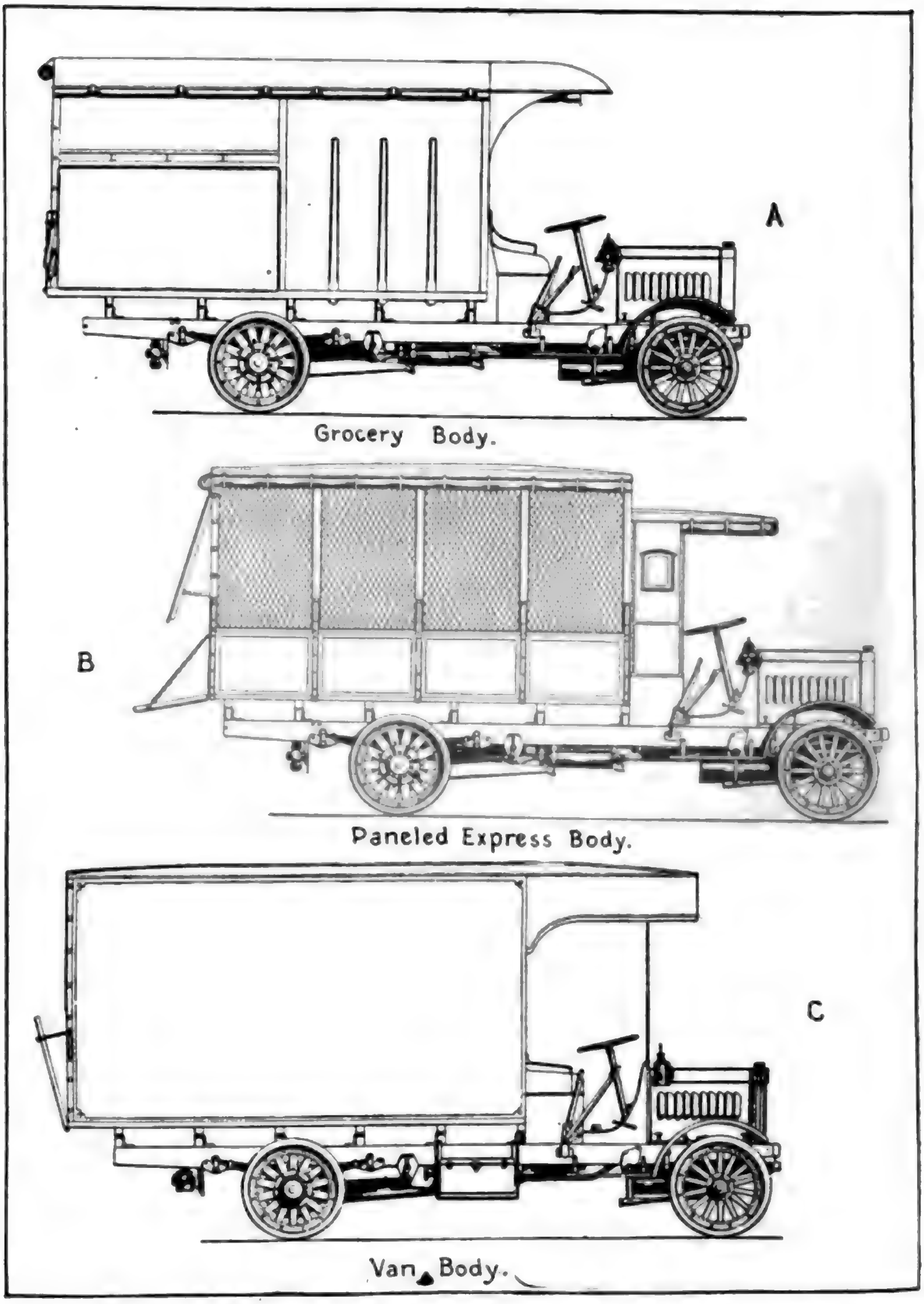
A
Grocery Body.
B
Paneled Express Body.
C
Van Body.

Fig. 29.—Examples of Express and Van Body Designs.

with or without signboards and cab. The winged and slatted side sections, of which three are provided on each side, may be removed, if desired, and a plain platform truck obtained.

The transfer body outlined at D has winged panels and removable stake gate at the sides, with a paneled end gate. This is recommended for handling coal in bags, hardware, brick, ice-cream, and also for meat packers. It is also useful in moving milk in large cans, concrete pipe and blocks, and for furniture and piano moving. The body is 12 feet 8 inches long, 5 feet 8 inches wide, and 2 feet 6 inches high, all these being inside dimensions.

Covered Body Designs.—A group of covered bodies is shown at Fig. 29. That depicted at A is known as a "grocery" body, and has combination panel and removable stake sides with end gates. It has a permanent canopy top, which extends over the driver's seat, and which is provided with side curtains. It is recommended for the use of wholesale grocers and drug houses or firms handling similar lines of goods which come in packages of a wide variety of shapes and sizes. The side stakes permit loading or unloading from the front. The paneled express body, shown at B, has a fixed top and driver's cab, with rolled curtains. A wire screen side is provided between the panels and the roof. The tail gate is adjustable and may be dropped down to facilitate loading, and the wire screen frame between the tail gate and the roof is also adjustable. The van body shown at C is fully enclosed with solid paneled sides and a permanent top which extends over the driver's seat. A large solid tail gate is provided. This van body is suitable for storage warehouses and furniture moving for department stores, and for handling all light, bulky material. The body is 14 feet long, 7 feet wide and about 7 feet high, inside measurement.

Special Purpose Bodies.—A group of special purpose bodies is shown at Fig. 30. That at A is suitable for brewers, bottlers, mineral water manufacturers, or for any material carried in small crates, cases or boxes. It can be used for handling liquids in barrels, and also solid materials such as lime, cement, flour, sugar, etc., carried in the same kind of containers. The ice-dealers' body, shown at B, has low paneled sides, with the posts outside, a running board at the side, and a large drop tail gate. This body can be used to advantage by wholesale and retail ice dealers, for carrying coal or coke in bags, for handling firewood in stove lengths, milk and cream in cans, cement or lime in bags, etc. It is 12 feet long, 5 feet 8 inches wide, and 4 feet high. The metal body, especially designed for dairy use, shown at C, is a sheet metal refrigerator type box body with steel roof, and having clamping side doors. It is suitable for handling milk and cream, ice, ice-cream, and similar materials. It is 11 feet 11

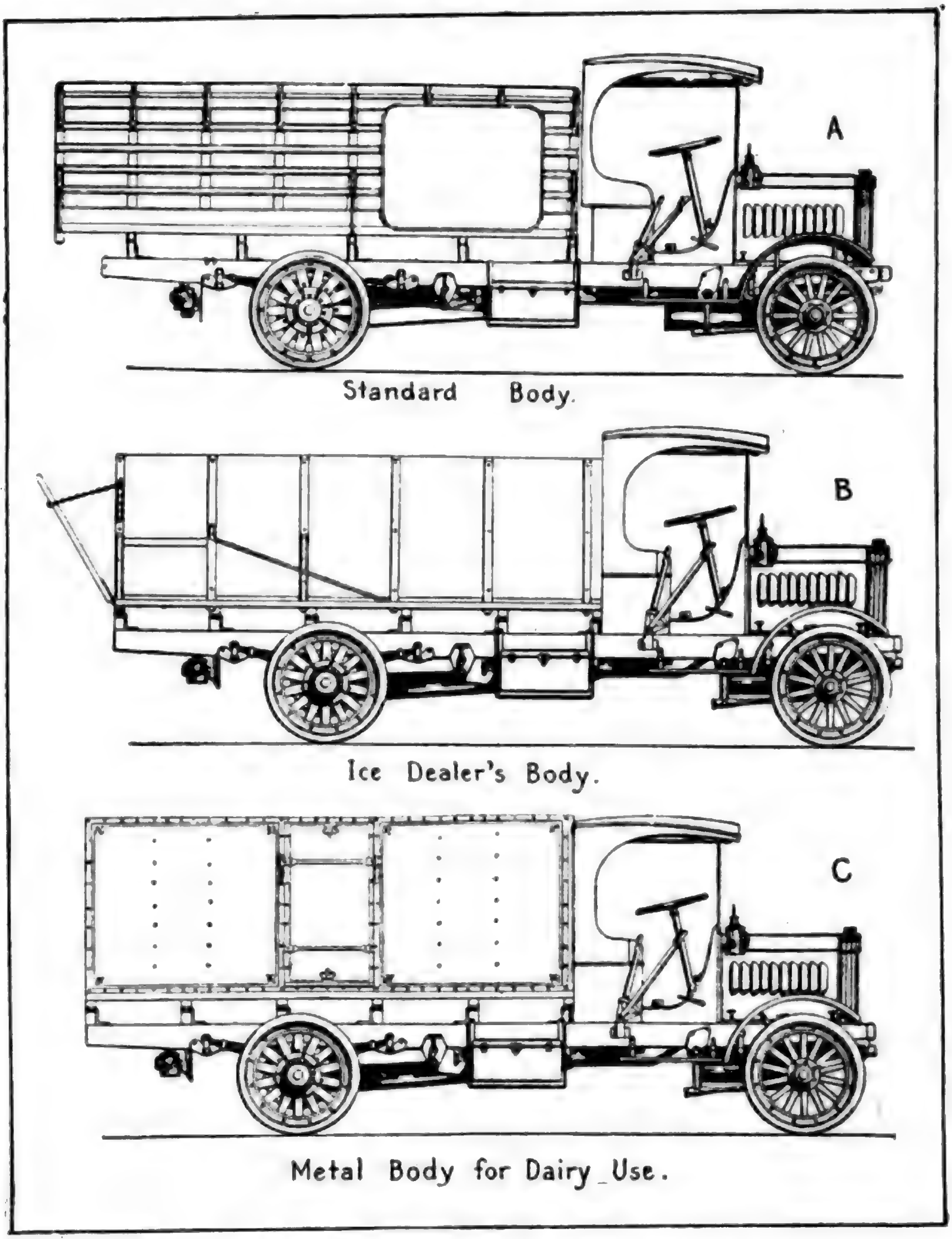
A
Standard Body.
B
Ice Dealer's Body.
C
Metal Body for Dairy Use.

Fig. 30.—Typical Special Duty Bodies.

inches long, 6 feet 5 inches wide, and 4 feet high. It can be had with a rail around the roof, for carrying extra cases of bottled milk.

Two forms of bodies for handling heavy materials are shown at Fig. 31. That at A is known as the "brewery" body and has paneled sides, with flare boards on top and a driver's cab. It has removable stakes at the sides and a rear end gate. It is suitable for carrying all barreled liquids. The self-dumping coal body, shown at B, is of steel, having a sloping bed and chutes at both sides. It is suitable for coal, sand, gravel, ashes and material of that nature. It is 12 feet 11½ inches long, 6 feet 2½ inches wide, and 3 feet 1 inch high, inside measurement.

Bus Body Designs.—Three forms of passenger-carrying bodies are shown at Fig. 32. That at A is the double-deck bus body, similar to the form used on Fifth Avenue, New York City, and in London. It may be had with the open smoker's compartment, as shown, or completely enclosed. The body is a wood and metal structure, having a rear platform of metal, and stairs of that material leading to the upper deck. It is suitable for city passenger service or as a railroad feeder. The capacity is fifty persons, twenty-four in the main body and twenty-six on the upper deck. The design shown below it at B is a single-deck bus which is also a composite wood and metal body construction. All windows may be dropped and are provided with shades and alternate windows have top ventilators. The driver is completely enclosed. This type is suitable for city and sub-

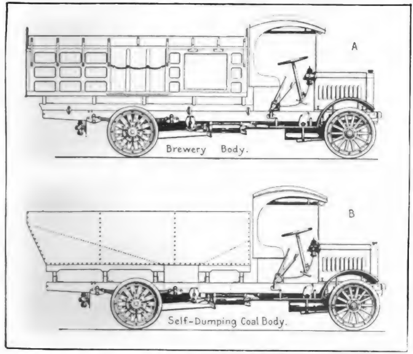

Fig. 31.—Body Design Shown at A Suitable for Brewery Use. That at B is a Special Self-Dumping Coal Body.

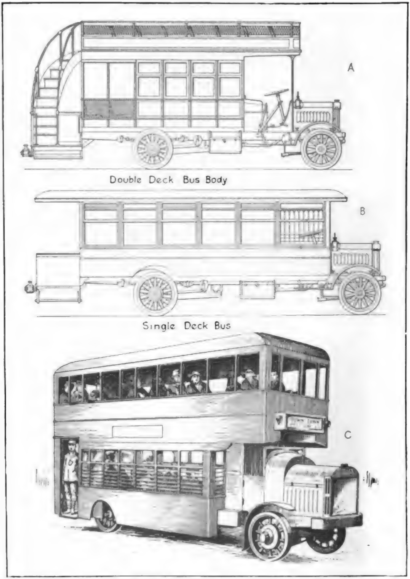

Fig. 32.—Examples of Motor Bus Bodies. Type at A is English Design or Fifth Avenue Bus Type. That at B is a Form Very Popular on the Paris Boulevards. That Illustrated at C is a Double Deck Form Used in Chicago.

urban passenger service, and for renting to theater parties, schools, institutions, film companies, etc. This form of bus is extensively used in Paris.

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A motor bus with a covered upper deck has made its appearance in Chicago as a part of the fleet of the Chicago Motor Bus Co. It is shown in Fig. 32, C, and differs radically in construction from the New York or Paris types of bus. The description which follows is taken from "Automotive Industries." Mechanically, it is the same as those that have been operated there for the past three years. Like the older type, it has the front wheel drive, the floor on a level with the curbing for convenience and speed in taking on and off passengers, and the covered straight stairway that is safer than the winding and exposed one. The difference lies in the covered top with glass windows in the sides, and in the seating capacity. Whereas the older type of vehicle would accommodate 51 passengers with seats, the new bus seats 60. Instead of the 22 enclosed downstairs seats in the old style bus, there are 60 enclosed and protected seats, 24 below and 36 above.

The length of the car is 25 feet, the width 7 feet 6 inches, and the height from roadway when unloaded, 12 feet 11 inches, and 12 feet 8 inches when filled. The wheel base is 176 inches, height of the lower deck from the roadway being 12¾ inches. Both decks are lighted electrically by current from a generator driven by the engine. The vehicle is heated by exhaust gases from the engine, which pass through pipes placed near the floor in the lower interior of the car. The front tires are 6-inch singles, while those in the rear of the same size are duals. The power unit is the American Motor Bus Company standard type of front wheel drive, made detachable and with a constant mesh transmission. The worm drive also is used. The brakes act on the rear wheels and have approximately 500 square inches of braking surface. However, the salient feature of the new bus is the roof over the upper deck. This cover is light and is not too high to easily clear elevated structures and trolleys under which it must pass. Because of the low level of the upper deck the center of gravity in relation to the roadway is low, thus minimizing unpleasant swaying.

The front wheel drive and low hung body make the stepless feature possible. It allows the passenger to enter or leave the bus directly from the surface of the sidewalk. The only steps in the vehicle are those leading to the upper deck. They are straight and enclosed.

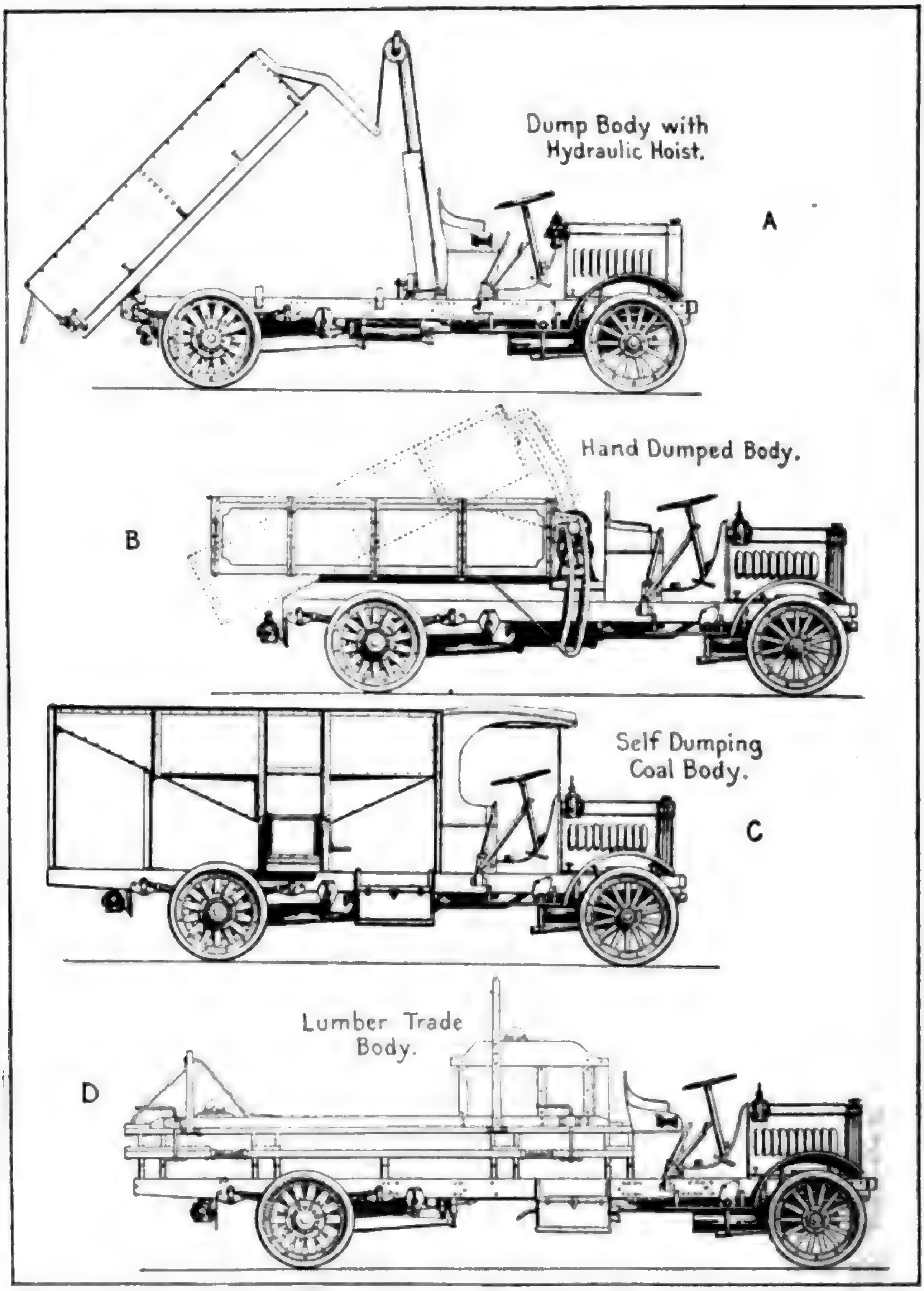
Dump Body with Hydraulic Hoist.
A
Hand Dumped Body.
B
Self Dumping Coal Body.
C
Lumber Trade Body.
D

Fig. 33.—Special Bodies for the Coal Business are Shown at A, B and C, While A Distinctive Design to Facilitate Handling of Lumber is Shown at D.

Dump Bodies.—Several interesting forms of movable bodies are shown at Fig. 33. That at A is a dump body, provided with a hydraulic hoist. The body is of steel and it will hold four tons of crushed rock or three of soft coal. It may be tilted to a

45 degrees angle and the steel tail gate operates automatically to permit discharge of the load. This type body is a popular one with excavating contractors. The length inside is 9 feet 8½ inches, the width is 5 feet 6 inches, and the height 2 feet. The sheet steel body at B is a hand-dumped type, the front being elevated through a curved rack and a pinion which is turned by reduction gearing operated by a hand crank. It is suitable for the same material as the dump body with hydraulic hoist shown above it. A self-dumping coal body, which is an all-steel construction, is shown at C. This depends on the gravity principle of unloading just as the body outlined at Fig. 31, B, does. It is suitable for the same kind of work, but is sometimes preferred because of the greater height of the chute doors from the ground, which assist in its self-dumping qualities in many instances. The three-ton body has 120 cubic feet capacity. The four-ton, 160 cubic feet capacity.

The lumber body, shown at Fig. 33, D, is suitable for handling long timbers or planks in quantity. It is provided with rollers and side guards and is a very satisfactory form for loading lumber where trailers are impracticable or prohibitive. It may also be used for handling pipe, poles or other long material. It is 15 feet 3 inches long, 5 feet 8 inches wide. The front stake is 4 feet 6 inches and the rear stake 2 feet 4 inches high.

Semi-Tractor Bodies.—The utility of the semi-tractor outfit has been recognized by many manufacturers and two forms are shown at Fig. 34. That at A is a wood, bottom-dumping, two-wheel trailer with very large and wide steel-tired wheels. The front end is supported by a fifth wheel or turntable arrangement on the tractor. This outfit is well suited for contractors and for handling any kind of material that can be hauled profitably in a dump body. It is sometimes necessary to haul very bulky and heavy merchandise, and also machinery and large slabs of cut stone which would call for the expenditure of considerable energy to raise to a platform of the usual height. The low gear, semi-tractor outfit shown at Fig. 34, B, is a practical solution of the heavy hauling problem.

Tank Bodies.—Two interesting designs of tank bodies are shown at Fig. 35. That at A is a plain sheet steel tank, which is held in notched bolsters by steel bands. Any number of top filler openings and rear outlets may be provided and the tank may be round, oval, or rectangular in cross sections, and be

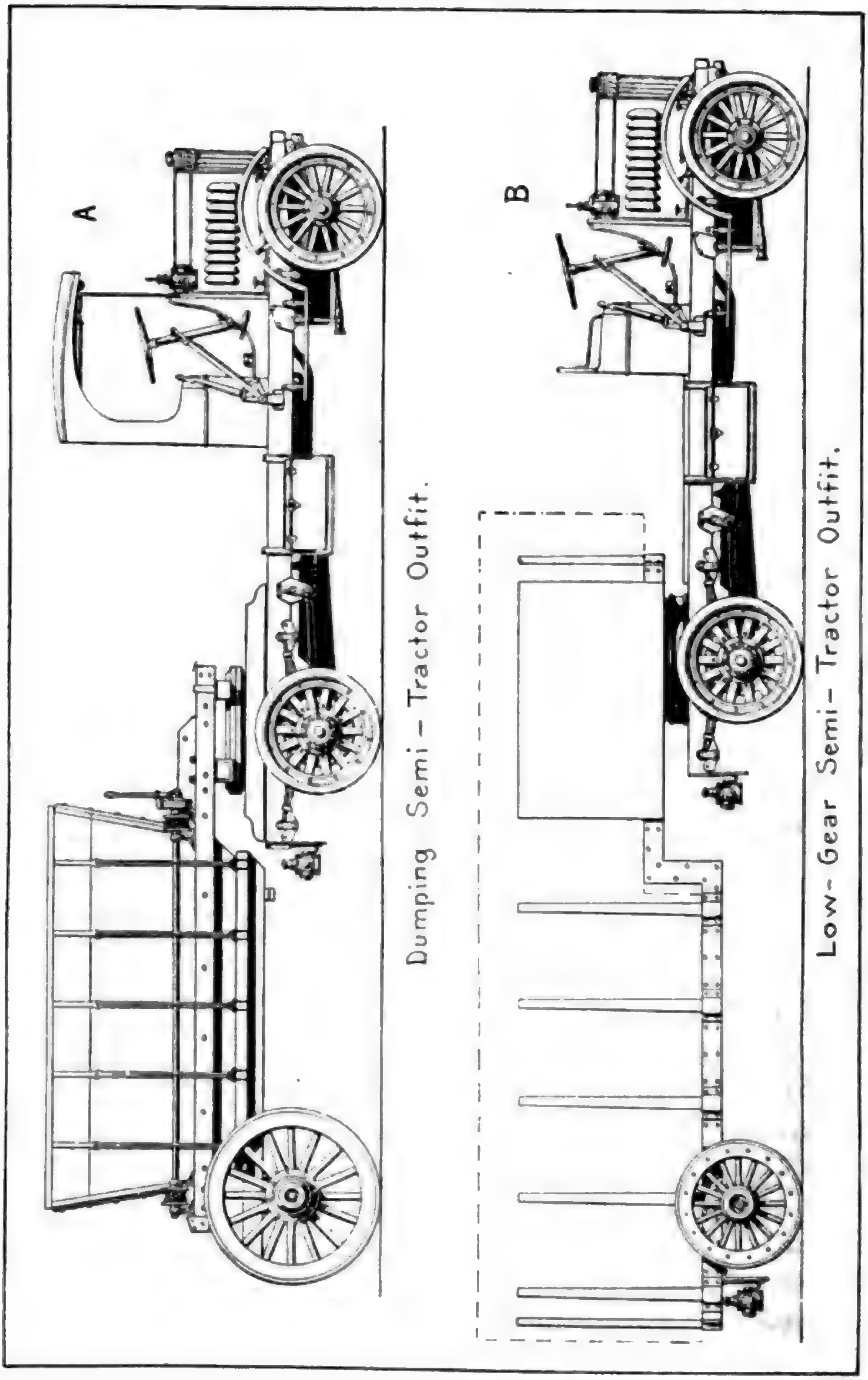
A
Dumping Semi - Tractor Outfit.
B
Low- Gear Semi- Tractor Outfit.

Fig. 34.—Typical Semi-Tractor Outfits. At A, a Dumping Body is Shown, While at B, a Low Gear Suitable for Handling Heavy and Bulky Materials is Outlined.

divided to any reasonable number of compartments suitable for hauling water or for oils, gasoline, kerosene, and other liquids of that nature. The standard three-ton chassis accommodates a 750-gallon tank, while the four-ton will carry 1,000 gallons. The wooden tank body, shown at B, is suitable for oils, vinegar, brine, malt liquors, and bulk transportation of any liquid. It is equipped with a power-driven centrifugal pump for filling purposes; sizes vary with truck capacity and weight of material to be hauled. The tank diameter may be anything up to 5 feet and the length up to 15 feet.

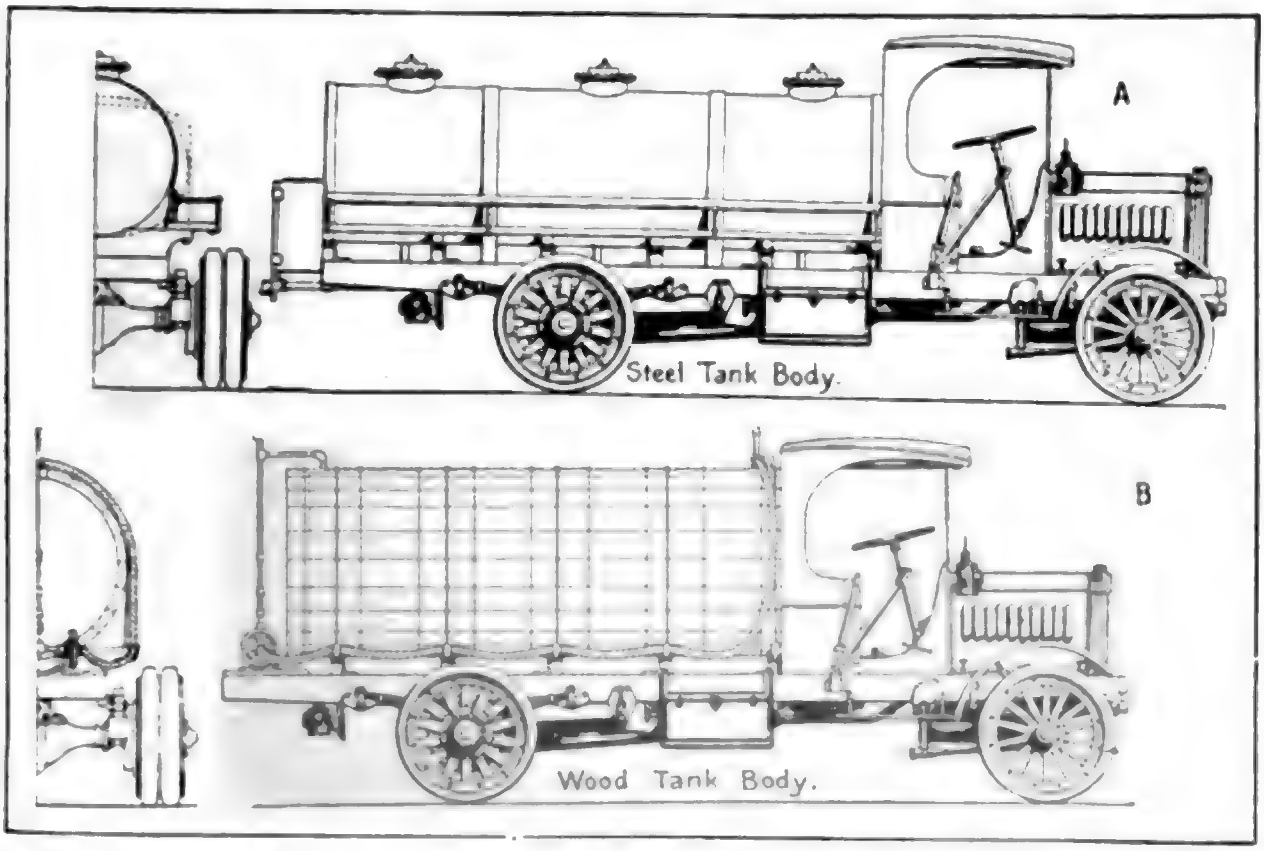

Fig. 35.—Typical Tank-Body Designs for Transforming Liquids. Three Compartment Body With Shelves and Rear Closet to Carry Oil Cans and Measures Suitable for the Oil Trade. At B, a Wood-Tank Body for Carrying Liquids that Will Attack Metal with Special Transfer Pump Attached is Shown.

Selden Five-in-One Combination Body.—A combination convertible body for truck chassis has been developed by the Selden Truck Sales Co., and is illustrated at Fig. 36, which can be supplied to order with Selden machine, which is claimed to meet satisfactorily practically all the needs for general haulage. It is especially suited for farm work where the loads carried vary widely in bulk, and converted as necessary the machine may be made very economical and of time and labor. In the accompanying illustration a one-ton Selden special chassis is shown equipped with this body, which is known as the "Five-in-One."

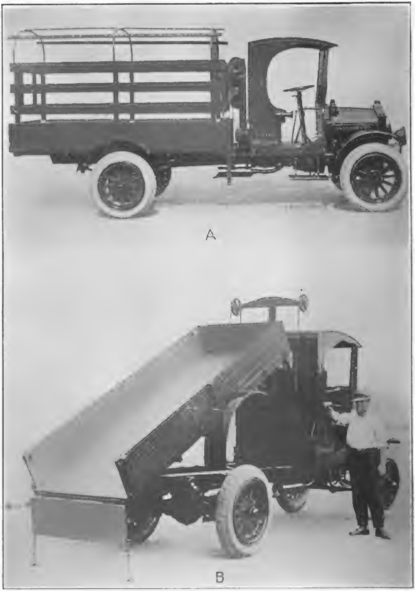

Fig. 36.—Special Combination Body on One-and-One-Half Selden Special Chassis. View at A Shows the Body with Rack Sides and Top Hoops. View at B Shows Use of the Body When Raised by the Hand-Operated Mechanical Hoist.

This body can be as required a platform, express, open stake and rack, covered stake and rack and end-discharge or dumping, and as illustrated at A the body is complete. The conversion can be made quickly and without special tools or heavy labor. The platform is constructed to have space 120 inches long and 44 inches wide, with the sides and ends in place. The sills and bolsters are oak and the floor and the side panels are yellow pine ⅞ inches thick, reinforced with ten gauge guard irons. The stakes are oak, 1¾ x 2½ inches, and the stake panels are ⅞-inch yellow pine. As constructed the body has a permanent front end or panel, but the sides and tail gate are removable, the sides being mounted with stakes seated in pockets.

The platform without the sides and tail gate can be utilized for hauling brush, logs, cordwood, farm machinery, etc., and with the addition of the 14-inch sides and tail gate it becomes a standard type open express body that can be used for general purposes. As this body can be elevated by a manually operated hoist, as outlined at B, it can be used for hauling grain, sand, gravel, coal or any commodity that can be quickly discharged. Fertilizer can be hauled and piled or spread as may be desired. With these bodies contract work can be undertaken with reasonable certainty of good returns. The rack sides and ends can be quickly installed in the sockets on the sides and the edges of the platform, and the body is then adapted for carrying light and bulky loads, or it is suited for carrying cattle if these are to be transported such a distance that walking would cause a shrinkage of weight.

If the loads are to be made up of fruit or vegetables, such as berries, peaches, grapes, tomatoes, celery, asparagus, melons, or farm crops that can be placed in baskets or crates, racks or light platforms placed between tiers will effectually prevent damage. In the event of storm a tarpaulin cover may be supported by three top bows of three-quarter-inch iron pipe, the ends of which fit into top sockets in the stakes, these bows being maintained in position by oak battens two inches wide.

Four-in-One Truck Body.—A type known as "Four-in-One" bodies for power trucks is now built commercially by the Simplex Mfg. Co., of Conneautville, Pa. This body is constructed to a standard design and is adapted for chassis from 1 to 3½ tons. The body can be used for a great diversity of work, as it may be at will a clear platform, stake platform, express or end-dis-

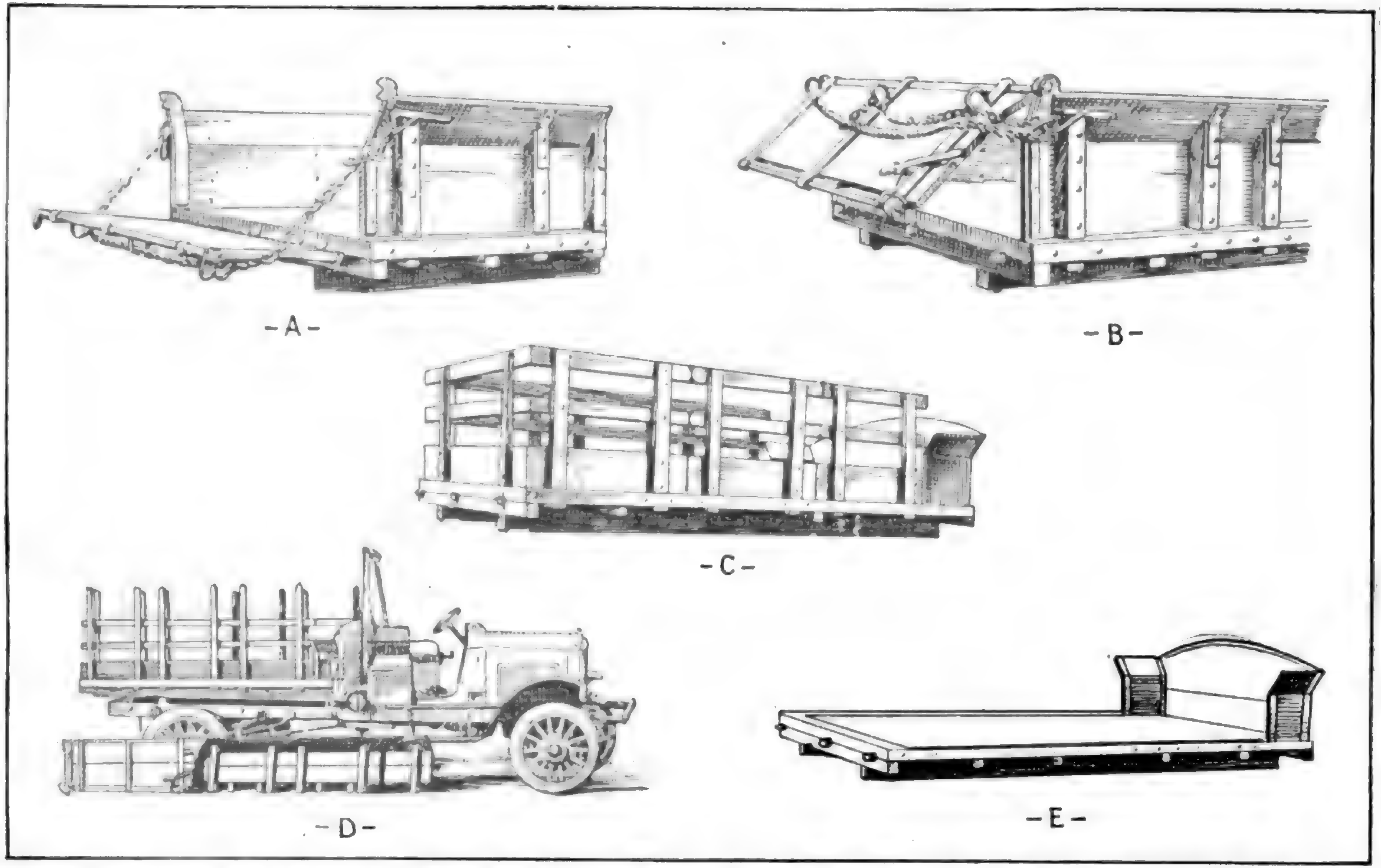

Fig. 37.—Simplex Four-in-One Body; A, Express Body with Flare Board Sides, 15 Inches High and a Dropped Tail Gate; B, with Swinging Tail Gate for End Dumping When Hand Hoist is Used; C, Regular Platform Body with 42-Inch Sides; D, Simplex Body Complete with Extra Parts; E, the Simple Platform Body with All Parts Removed.

charging, the time required for conversion being very brief. The body is strongly built of high grade materials, and it is reinforced with steel angles and straps to obtain maximum strength with comparatively light weight and to protect it against wear. It is built on a series of seven bolsters that are mounted on the side sills, and these sills are hinged at the rear of the chassis frame and are carried on the hinges and two crossbars. The deck of the platform is encircled with a heavy steel strap, and at the front and the sides are a series of stake pockets formed in the deck with strong reinforcements at either side of each pocket.

The sides, front and tail gate are 15 inches high, with the sides formed with flare boards, and the standard inside dimensions are from 90 to 138 inches long and from 52 to 58 inches wide. The tail gate is either dropped to any desired angle or it may be swung from the top and retained with a latch until the cargo is to be discharged. The chassis is fitted with a manually operated hoist, the lift being by a cable wound on a shaft and actuated by a hand crank through a train of gears. Statement is made that the body can be elevated to maximum height in forty seconds, and lowered in even less time. The tower of the hoist is heavily built and yet requires but nine inches space back of the driver's seat or cab. The manufacturer claims that the body can be converted from an express type to a clear platform in approximately three minutes, and that the platform or stake platform can be converted to an express type in a very brief time. The body is particularly adapted for farm work, for contractors' use, or for any service where a series of bodies would ordinarily be necessary to obtain maximum efficiency.

Industrial Trucks.—Several distinctive types of small motor trucks propelled by either electric or gas engine power have been designed to replace wheelbarrows, hand trucks, and other means of transportation within the buildings of a factory warehouse or manufacturing plant, and in the yards surrounding these buildings where standard size trucks could not be used on account of the lack of economy of such vehicles on very short haul work. These industrial trucks and tractors provide a wide variety of industries with quick, economical and adequate interdepartmental transportation. Most of the industrial trucks have sufficient tractive ability so that they can haul ordinary forms of hand-drawn trucks or specially constructed vehicles as trailers, and thus increase their carrying capacity.

A special form of gasoline truck tractor, designed especially for industrial use, is shown at Fig. 38. The view at A is a plan of the chassis, showing the location of the various parts comprising that assembly, while the cut below it shows the completed vehicle equipped with a steel box or cargo body. The machine is a three-wheel form, the power being transmitted to the two front wheels through the medium of an internal gear reduction axle, while the single rear wheel which is mounted in a modified form of bicycle fork permits of turning the truck around sharp corners. It is a short wheel base, especially designed for use in factories where the aisles are narrow, turns sharp, and where constant transportation of raw materials or goods in process is necessary. The truck tractor has a carrying capacity of one and a half tons and sufficient tractive ability to pull heavily loaded trailers at the same time. It is simple in design, has a low center of gravity, as well as good ground clear-

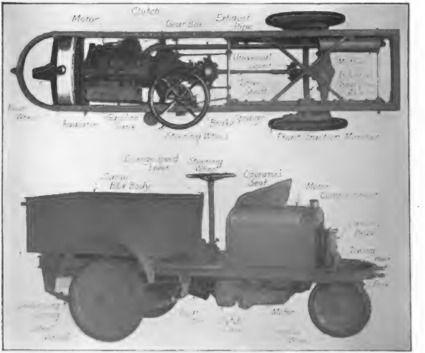

Fig. 38.—View at A Shows the Chassis of the Clark Truck Tractor. A Gasoline Engine Driven Type Suited for Industrial Use in Factory Yards and for Interdepartment Communication. Side View of Truck at B Shows Unconventional but Strong Design.

ance. It is but 42 inches wide, which is narrow enough to pass through most aisles and doorways. The ratio of speed provided enables it to travel as slowly as one-fourth mile per hour. It may be turned around in a circle of 72 inches radius. The ground clearance of 9½ inches makes it possible to operate through snow, sand, and over rough ground, and a maximum speed of fifteen miles per hour is possible, if desired.

The engine is 25 horse power, 4-cylinder type, having L-head cylinders cast in a block with a bore of 3⅛ inches and a stroke of 4½ inches. Ignition is by high tension magneto, lubrication by circulating oil pump and cooling by the thermo-syphon having an exceptionally large radiator to prevent overheating. The clutch is a dry plate, multiple disc type, and the transmission the usual three-speed forward-sliding gear pattern. Both clutch and transmission are combined with the engine as a unit. The drive from the transmission is by a double universal joint shaft to an internal gear drive axle. The front springs are the usual semi-elliptic forms and are underslung, due to the use of a single rear wheel; a coil spring is carried in an air cylinder to provide a shock-absorbing feature. A specially large brake of the external constricting type acts on a brake drum immediately behind the transmission. The wheels are single piece metal discs, and may be equipped with either solid rubber tires or with extra width steel tires, provided with traction lugs. When rubber tires are used, 28 x 3½ are used in the rear and 30 x 3½ in the front. The weight of the cargo body type is 2,050 pounds, the wheel base 72 inches, the tread 35½ inches, the overall length 112 inches. The body is 50 x 36 x 19 inches. A dump body type is manufactured which has a wheel base of 84 inches and a weight of 2,450 pounds. The over-all length is 125 inches and the body will hold one cubic yard of material. The gasoline consumption is given as three gallons per day when used in the average manner.

The Towmotor, shown at Fig. 38C, is an industrial tractor, driven by a gasoline engine, instead of the usual electric motor and storage batteries. It is designed to tow or push standard trucks or load carrying vehicles or skids about plants for twenty-four hours per day. Gasoline is used as the motive power. The tractor is a rugged, all steel machine, built of the highest grade standard units, and able to withstand much hard use and abuse. It is not a remodeled automobile, but has been designed and built to fulfill the special requirements of industrial haulage. The machine has sufficient capacity to move freight cars and still operates economically on light loads. The Towmotor is fast, powerful, and requires but little attention. The motor torque and drive ratios furnish a draw-bar ability approximately three times the tractive ability of the tires over average surfaces. Under average conditions this represents a trailing load of 10 to 15 tons. By special hook up and traction arrangements a considerably larger per cent of the reserve torque of the motor can be utilized in such exceptional cases as spotting loaded freight cars.

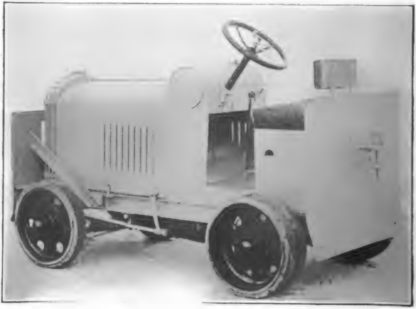

Fig. 38C.—The Towmotor Industrial Gasoline Tractor.

The power plant is a four-cylinder, four-cycle, 3¾ x 5½ S. A. E. rating 22.5 horse power, capable of delivering 40 horse power at 2,000 r.p.m. and is a long stroke type with removable cylinder heads and overhead valves. Forced lubrication to all crankshaft bearings. Large bearing surfaces throughout. All motor parts fully enclosed and protected from dust. A centrifugal type governor is integral with motor and fully enclosed. This is adjustable to govern at suitable speeds 1,000 to 2,000 r.p.m. according to plant conditions. Battery type ignition with spark lever control at steering column is used and a six volt starting motor with automatic Bendix type of drive mechanism. The clutch is a ten inch, single plate, heavy duty clutch which has a simple adjustment and is smooth in action. The gear is a Standard selective type in unit with motor, three speeds forward, one reverse. Standard automobile control with dust proof ball and socket pivot.

The rear axle is a special adaptation of the Internal gear type of drive which is highly efficient for both low speed breakaway pulls and light duty. Reduction ratio, 8:1. Steering is by truck type sliding block steering column, with spark and throttle control and horn button. Steering connection to front wheels only. Semi-elliptic special steel springs at front axle only. Cast steel disc wheels are used, shod with solid rubber tires pressed on type, interchangeable front and rear. Front, 22 x 3½ Single. Rear, 22 x 3½ Dual.

The frame is pressed steel, four-inch channel section, and is provided with heavy steel plate bumpers, front and rear full width of chassis, giving protection to vital parts in case of collision or pushing operation. Front and rear drawbar hooks are adjustable in height. A nine gallon gasoline tank amidships at cowl furnishes gravity feed to carburetor. The radiator is a fin and tube type removable core in cast sectional housing. Internal expanding type brakes at rear wheels are controlled by either hand lever or foot pedal. The specifications follow:

Weight, 3,200 pounds; wheel base, 60 inches; length over all, 90 inches; tread, 44 inches; width over all, 52 inches; turning radius over all, 10 feet. This permits practical operation through seven foot aisle intersections. Speed is one to 15 miles per hour and may be controlled by governor.

Electrically Propelled Industrial Trucks.—Two forms of electrically propelled industrial trucks are shown at Fig. 39. In one of these the storage battery and the electric motors driving the wheels are carried at the front end of the truck. In the other the storage battery is carried beneath the truck floor. The control of these is very simple. One handle operates the current controller, while the other is employed for steering. The driver stands erect on a platform at the end of the machine, and as soon as he steps off the current is automatically interrupted and the truck cannot be operated until the operator's weight brings the platform to a horizontal position and again closes the circuit.

All types of electrical trucks are characterized by a short wheel base and short turning radius, this being attained either b he use of three wheels or by combined driving and directive . ..-bers when a four wheel drive is employed. The general pr. ci-ples of construction are the same as used in the full size lec-trically propelled trucks, which are described in a special chapter.

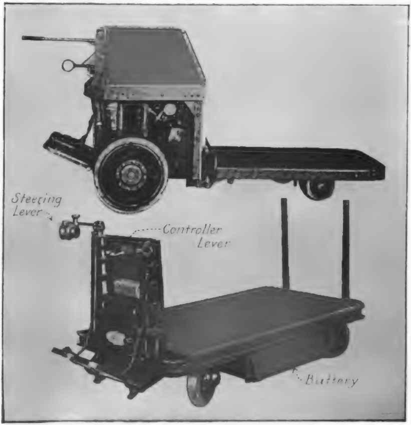

Fig. 39.—Small Electrically Propelled Industrial Trucks Used for Handling Baggage, or for Interdepartment Transportation.

Ford Truck Conversion Sets.—Another development worthy of mention is the large sale of adapters, special rear axles, auxiliary frames, etc., devised to transform a popular light-weight delivery car chassis, shown at Fig. 40, into a one-ton capacity truck. These have not been used under varying conditions long enough yet to determine their real value and influence on the depreciation of the power-producing elements of the original

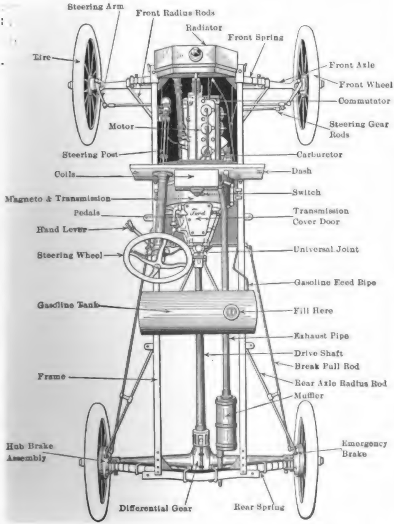
Steering Arm
Front Radius Rods
Radiator
Front Spring
Tire
Front Axle
Front Wheel
Commutator
Motor
Steering Gear Rods
Steering Post
Carburetor
Coils
Dash
Magneto & Transmission
Switch
Pedals
Transmission Cover Door
Hand Lever
Steering Wheel
Universal Joint
Gasoline Feed Pipe
Gasoline Tank
Fill Here
Exhaust Pipe
Drive Shaft
Break Pull Rod
Frame
Rear Axle Radius Rod
Muffler
Hub Brake Assembly
Emergency Brake
Differential Gear
Rear Spring

Fig. 40.—Plan View of Ford Chassis Showing Relative Location of Important Parts.

chassis which have not been strengthened proportionately as the load-carrying members have. These devices, which are outlined in Fig. 41, can be divided into five general classes. In the types outlined, that at A retains the Ford rear axle and spring, but the wheel base is increased by the introduction of a section in the frame at either of the two points shown, and the drive shaft is also increased in length to correspond to the increase in wheel base. The type shown at B provides for additional load capacity by the use of supplementary springs attached directly to the housings of the drive gearing actuating the steel wheel. These wheels are carried on special bearings independent of the Ford rear axle, so this member is used merely to transmit power and is not subjected to the strain of carrying the vehicle load. In class C the rear axle is used for a jackshaft for

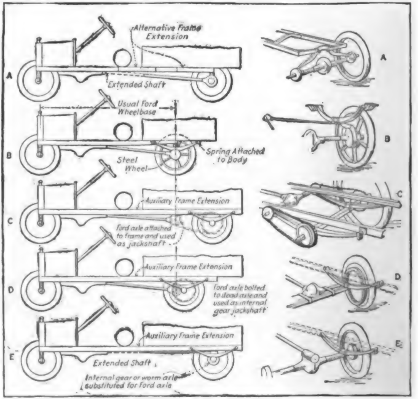
Alternative Frame Extension
A
Extended Shaft
A
Usual Ford Wheelbase
B
Spring Attached to Body
Steel Wheel
B
C
Auxiliary Frame Extension
Ford axle attached to frame and used as jackshaft
C
D
Auxiliary Frame Extension
Ford axle bolted to dead axle and used as internal gear jackshaft
D
E
Auxiliary Frame Extension
Extended Shaft
Internal gear or worm axle substituted for Ford axle
E

Fig. 41.—Diagrams Showing Classification of the Various Conversion Sets Marketed to Convert Ford Standard Model T Chassis to Truck Service.

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a chain-driven rear-end truck assembly, which is a unit with a supplementary frame extension adapted to be easily attached to the regular chassis. The design shown at D is similar, except that the rear axle is changed into a jackshaft for an internal gear-driven unit. Instead of sprockets on the axle shaft ends as at C, spur pinions which mesh with large internal spur gears driving the wheels are employed. In the type shown at E, an auxiliary frame extension is used, but this carries a worm or internal gear drive axle and special wheels and springs. The Ford rear axle is not used at all, nor are the Ford rear wheels. Those types in which the load is carried on special springs and axle members, as at B, C, D and E, are much stronger than that outlined at A. The regular rear end construction was never intended to carry heavy loads.

Motor Truck Ability.—Ability is a term which is widely used by truck salesmen to denote the capacity or power of a truck in its relation to climbing grades, carrying loads and overcoming road resistance. Hill climbing ability depends entirely on the gear ratios provided in the driving system for trucks of the same weight and horse power. Under the same conditions the truck that has the lowest road speed on any given transmission lever position will be the best hill climber. As will be explained, gear reduction is but a form of leverage; it permits the power plant to run at such speed that it is delivering its full power and yet the truck may be moving very slowly. The factor that determines truck ability is really the tractive effort, and this in turn is governed by: the gradient generally expressed in percentage; the gross mass to be moved, this including the weight of both truck and its load; the tractive resistance offered by the road, which will vary with the character of the surface. The tractive effort produced by the truck power plant depends on the size of the engine and its horse power output at a definite speed of rotation, the power loss due to friction in the mechanism, the total leverage or gear reduction between the source of power and the traction members and the diameter of these driving wheels. A simple formula for total tractive effort may be expressed as follows:

$$\frac{P \times 33{,}000 \times 60 \times e}{\text{Miles per hour} \times 2{,}580} = \text{tractive effort.}$$

In the above **P** is the brake horse power of the engine and e is the mechanical efficiency.

Drawbar Pull.—The drawbar pull or horizontal force necessary to move a vehicle over a level road overcomes road resistance and may therefore be taken as a measure of its value. This is usually considered in pounds of pull necessary to move the weight of a ton, and it will vary with the material of which the road is composed and the kind of tires used. The road resistance of sand or gravel is very much greater than that of smooth asphalt or macadam. Conditions making for poor traction usually increase the road resistance. It requires less power to move a load on pneumatic tires than it does on solid rubber. The limit of traction efficiency is about 60 per cent of the total weight on the traction wheels, if operated on dry asphalt paving and if the wheels are shod with rubber tires. This means that a motor truck in which the weight on the rear wheels was 10,000 pounds the limit of pull that could be applied at the point of contact of the driving wheels and the ground would be 6,000 pounds. For this reason the engine power and gear ratio must be proportioned so that no more than this maximum amount of tractive force will be exerted, as any more power would spin the wheels and would not serve any useful purpose.

Tractive Resistance of Roads.—A writer in the "Commercial Car Journal" outlined a series of experiments to determine tractive resistance of various urban roads and, while the article is too comprehensive to be reproduced at length, the summary of conclusions reached cannot fail to interest the reader. The first point considered is the various factors that may enter into constant resistance.

The constant resistance (1) may be briefly called the displacement resistance, item 2 the impact resistance, and item 3 the air resistance. The displacement resistance is low for hard pavements, and high for soft pavements (of low resilience). The impact resistance is very marked in granite block roads. The air resistance, at any definite velocity, is the same for all curves, because the air-resisting parts of the truck were left unchanged throughout the tests. An asphalt road in poor condition at a speed of 12.4 m.p.h., the displacement resistance is 0.84 per cent, the air resistance is 0.11 per cent, the impact resistance 0.20 per cent, and the total 1.15 per cent, equivalent grade.

The displacement resistance of a road manifestly varies, not only with the type and surface quality of the road, but also with the type, dimensions and quality of the tires on the wheels of the vehicle. In the tests here reported, the same tires were used throughout, and they remained in substantially the same condition.

The impact resistance of a road manifestly depends not only on the type and surface quality of the road, and the sizes of its irregularities, but also on the type, dimensions and quality of the wheel tires, the weight of the truck, and the quality of its springs.

The air resistance per unit weight of truck manifestly depends upon the weight, dimensions and shape of the vehicle, as well as on the speed of the vehicle relatively to the surrounding air.

The wind resistance per unit weight of truck manifestly depends upon the weight, dimensions and shape of the vehicle, as well as on the direction and velocity of the wind and the velocity of the vehicle. It is assumed that at low wind and vehicle speeds, like those here considered, only that component of the wind which is in the direction of the vehicle's path needs to be taken into account, and that the mean of the wind resistance in opposite directions, along the roads, is zero.

Summary of Conclusions.—The following conclusions are indicated from the preceding results: As confined to urban roads, with a solid rubber tired motor truck between the speed limits of from eight to 15.5 m.p.h.

1. The overall efficiency of the test-truck mechanism between battery terminals and rear wheel treads reached a maximum value of about 78 per cent under the most favorable conditions.
2. The mechanical efficiency of transmission from motor shaft to rear wheel treads, for the truck tested, shaft-driven through a single reduction worm gear, was found as high as 90 per cent.
3. Tractive resistances are most conveniently expressed as an equivalent percentage grade, i.e., a level road of definite tractive resistance may be regarded as a road of zero tractive resistance, but rising uniformly X units in 100 units of road length, or having an equivalent grade of X per cent.
4. Under the conditions of these tests, the tractive resistance on level roads, in the absence of wind, is composed of (a) displacement resistance, (b) impact resistance, and (c) air resistance.
5. The displacement resistance varied from 0.85 per cent, equivalent grade, for a hard, smooth asphalt or bituminous con-

crete, to 1.6 per cent for a very soft, tar-macadam road, and was practically constant, for all speeds considered, on any given road.

6. The impact resistance increases with the velocity, with the total weight of vehicle, and with increasing road surface roughness. In these tests, the impact resistance of good asphalt or bitulithic or other smooth pavement was practically negligible, and reached its highest values on granite-block roads with sand filled joints, and on badly worn macadam pavements. The rate of increase of impact resistance with speed was most marked on the roughest roads.

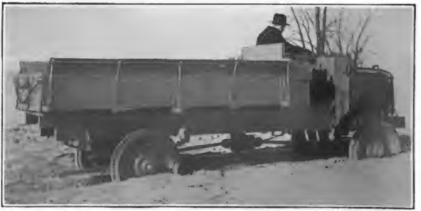

Fig. 42.—How the Four-Wheel-Drive Winther Model 439 Truck Can Surmount Unfavorable Highway Conditions.

7. At the vehicle speed of 12.4 m.p.h., the air resistance for the vehicle tested, assumed to be dependent only on the speed, was roughly 0.11 per cent, equivalent grade; i.e., from four per cent of the highest to 12.5 per cent of the lowest, total tractive resistance.

8. The following urban pavements are enumerated in the order of their desirability for vehicle operation from the point of view of tractive resistance at 12.4 m.p.h., as found in this investigation: Asphalt, wood-block, hard smooth macadam, brick-block, granite-block, with cement-filled points, cinder, gravel, granite-block with sand-filled joints.

9. The equivalent grade at 12.4 m.p.h. of a badly worn city macadam road was found to be nearly three times as great as that of the best asphalt road tested. This means, at this speed,

SUMMARY OF TRACTIVE RESISTANCES OF DIFFERENT URBAN ROADS AT DIFFERENT SPEEDS

All Tractive Resistances are Expressed in Equivalent Per Cent Grade

Type Road	Condition	Equivalent per cent. grade		Per cent. increase in tractive resistance from 10 to 12.4 m.p.h.	Comparative tractive resistance factors referred to asphalt roads, at	
		at 10 m.p.h.	at 12.4 m.p.h.		10 m.p.h.	12.4 m.p.h.
Asphalt	good	0.93	0.97	4	1.0	1.0
Asphalt	poor	1.03	1.16	11	1.11	1.20
Wood block	good	1.10	1.15	5	1.18	1.18
Brick block	good	1.12	1.21	8	1.20	1.25
Brick block	slightly worn	1.14	1.27	11	1.23	1.31
Granite block	good	1.83	2.16	18	1.97	2.23
Granite block with cement joints	good	1.16	1.37	18	1.25	1.41
Macadam, water bonded	dry and hard	1.06	1.17	10	1.14	1.20
Macadam, water bonded	fair, heavily oiled	1.63	1.76	8	1.75	1.82
Macadam, water bonded	poor, damp some holes	1.65	1.89	15	1.78	1.95
Tar macadam	good	1.17	1.27	9	1.26	1.31
Tar macadam	very soft	1.67	1.76	5	1.80	1.81
Tar macadam	many holes, extremely poor, soft	2.38	2.75	16	2.55	2.85
Cinder	fair, hard	1.25	1.39	11	1.35	1.43
Gravel	fair, dusty	1.37	1.50	9	1.47	1.55

a consumption of energy at wheel treads of nearly three times as much on level poor macadam roads as on good level asphalt roads.

10. Increasing the gross weight of the vehicle by 12 per cent, through load, was found to have no effect on tractive resistance within the observed speed limits for smooth roads in good condition; but on rough roads, a distinct increase in tractive resistance with this extra weight was observed.

11. The presence of a layer of dust, say ⅜ inch thick, on a fair macadam road, was found to increase the equivalent grade of tractive resistance, at all tested speeds, by about 0.15 per cent.

12. A freshly tarred and therefore very soft tar-macadam road was found to have an increased tractive resistance equivalent, at substantially all tested speeds, of about 0.5 per cent. The tires in this case sank about 0.8 inch into the roadbed, the gross car weight being 4,710 pounds.

13. The total range of tractive resistance equivalent grade covered in the tests was from 0.93 per cent, on the best asphalt road, at lowest speed, to 2.7 per cent, on the worst macadam road, at nearly the highest speed.

Six-Wheeled Truck.—Claim is made that actual demonstration and close tabulation of results appear to indicate clearly that the "six-wheel" or tandem rear axle construction with pneumatic tires on all wheels has steadier riding qualities, better traction, is less wearing of road surfaces, has lighter axles, smaller and lower cost tires and greater braking capacity, and the vehicle has greater operating radius.

This form of truck has six wheels, four of which are grouped under the rear end of a chassis in much the same form of assembly as the truck of the steam railroad coach. The development of this type machine was due to the strong conviction of P. W. Litchfield, factory manager for the Goodyear Company, which was expressed at a recent joint meeting of the members of the Detroit and Cleveland sections of the S. A. E. held at Akron, that the heavy tonnage truck would be some form having more than four wheels, an evolution that may be comparable to the railroad car construction practice of grouping pairs of axles in frames known as trucks and mounting one of these trucks at each end of a car. There was no endeavor made to perfect a truck design, but careful study was made of the practicability of pneumatic tires for vehicles built to haul heavy freights.

Large Saving in Tire Cost.—Special interest attaches to tire weight and cost, which are probably the factors that most deeply concern truck owners, and instead of using 48 by 12-inch pneumatic shoes, weighing about 398 pounds each, that are designed for five-ton trucks, with the tandem axle construction four 40 by eight-inch pneumatic tires, each weighing 119 pounds, are used. The four tires weigh 476 pounds against 796 pounds for the "giants," and as they are each 279 pounds lighter they can be handled far more easily, a matter of no small importance when changes are necessary, especially if the work must be done outside of a garage or service station. Not only this; the set of four tires will cost approximately a third less than the two larger tires. And as the same tire is used on all wheels, the number of spares is reduced to that which will insure continuous service. This form of truck is still in the development stage, but offers interesting possibilities for future improvement providing it proves out in extended service.

With reference to wear of roads, statement is made that the pneumatic tire would appear to win the approval of engineers, for the average road has the maximum base that is practical and the surface disintegrates under the impact of solid tires. With the weight of the truck carried on four wheels, road and truck engineers believe that the average highway will endure under a load up to seven tons with no more wear than would result from a 3½-ton load carried on two solid tires. Road economy undoubtedly appeals to the people, and there is belief that if this is obtainable with use of the six-wheel vehicle the result would offset any sentiment against the use of heavy vehicles on highways, and would further stimulate appropriations of money for highway improvement.

An advantage of pneumatic tires with the tandem axle construction that is emphasized by Goodyear engineers is greater operating radius and steadier riding. The vehicle is said to have greater road adhesion than the two-wheel type, and there is so little vibration of road shock that no water was spilled from a glass filled to within an inch of the top, placed at the rear of the truck body, when the machine was driven on rough roads. When moving over obstructions the chassis rise and fall is but half what would result with two-wheel drive types, and the vibratory stresses from road shock are greatly reduced, much increasing the comfort of the driver. During recent hauling tests made between Akron and Cleveland the shock absorption was so effective that the machine was driven 48.6 miles at an average speed of 26 miles an hour, and the average speed through heavy traffic when leaving Cleveland was eight miles an hour.

Having a road surface contact 27 per cent greater than that of the two 12-inch tires, the four eight-inch tires had decidedly better traction, which was claimed to be especially noticeable by comparison with dual solid and pneumatic tires on highly crowded roads, and in soft surfaces where the additional tire area prevented the wheels sinking and the truck stalling.

Because of the light weight of the smaller pneumatic tires, the total axle weight is greatly lessened with the four-wheel construction, and with four brakes there is a far larger degree of safety than with two larger wheels. One of the chief objections by engineers to the use of 48 by 12-inch tires is the extreme height of the center of gravity, for the load is high above the ground, but it is much lower and there is the added stability of four-wheel support with the experimental Goodyear truck. The illustration at Fig. 228, A, shows the truck, which weighs 10,700 pounds with a load of 17,200 pounds, or eight tons 1,200 pounds, a total of 27,900 pounds, or nearly 14 tons. This is three tons 1,200 pounds in excess of the normal load rating of a five-ton truck. This form of truck construction will be considered more in detail in a later chapter.

Factors Controlling Truck Size.—A very interesting paper was prepared by A. F. Masury, chief engineer of the International Motor Company, New York City, and published in the "Commercial Car Journal," which gives the conditions that control and restrict the maximum overall dimensions of motor trucks.

In general the restricting factors are physical and legal, the legal being to a great extent directly determined by and the result of the physical.

Motor truck designers are being constantly confronted by engineering and contracting problems that would require motor trucks of capacities greater than at present existent and practical. The designer finds few things in the nature of pure automobile engineering problems that would prevent him increasing the size of trucks.

The weight and dimensions of materials to be transported are constantly increasing, and it is the materials that are of prime importance in determining the size and type of vehicle to be used in their transport.

Existing Physical Factors.—(A) Overall Height.

The overall height of present motor trucks seldom exceeds 12 feet.

The height is limited by the headroom necessary to drive under such structures as:

Railroad Bridges (Grade Crossings).
Enclosed or top bridges.
Elevated Railroad Structures.
Overhead Trolley Wires.
Doorways of Buildings.
Ferryboats.

Railroad grade crossing bridges seldom provide less than 12 feet headroom.

Enclosed top bridges do not always provide as much as 14 feet clearance.

The doorways of modern garages, built to accommodate present motor trucks, are made with 12 feet 3 inch headroom. However, few garage doorways exceed 10 feet in height.

(B) Overall Width:

The overall widths of present motor trucks are in very few instances in excess of 96 inches. This dimension is limited by the distance between parts of such structures through which vehicles must be driven, as:

Doorways.
Elevators in Buildings.
Ferryboats.

Doorways of modern garages, built to accommodate present day motor trucks, are made with a clearance between the butts of at least 10 feet 9 inches, which allows sufficient space for the fastenings of the doors without interfering with vehicles as they pass in or out.

Elevators in modern truck garages are made 11 feet wide.

Overall widths are to a great extent controlled by conditions that minimize the clearance between passing vehicles and the clearances between passing vehicles and stationary objects, as posts, trees, poles, elevated railroad pillars, curbs, etc., and that make negotiation both difficult and dangerous.

Many state roads are paved over a width of but 16 feet; country roads are usually narrower than this.

The difficulties of operating in congested city traffic tend also to restrict widths; small vehicles are more easily handled.

The following tabulation shows the maximum width and height of motor vehicles allowed on the ferries going into the State of New Jersey:

STATEN ISLAND TRANSIT RAILWAY COMPANY

	Overhead Clearance	Width
Ferryboat, Tottenville	12′ 4″	7′ 5″
Ferryboat, Perth Amboy	12′ 6″	7′ 7″

PUBLIC SERVICE RAILWAY COMPANY

Bergen Point

Boat	Height	Width	Width Between Wheel Guards
Bayonne	11.7	10.0	7.9
Public Service	15.5	8.2	6.6
Public Service	15.5	9.9	9.1

Edgewater

Boat	Height	Width	Width Between Wheel Guards
Englewood	10.9	9.1	7.1
Leonia	12.8	9.3	7.3
Edgewater	10.9	9.6	8.0
Fort Lee	12.2	9.9	7.7

CARTERET FERRY COMPANY

Overhead clearance of boats	13′ 0″
Clearance of passageways	9′ 6″
Passageway between combings	7′ 6″

	Height	Width
Pennsylvania R. R.	12′ 4″	10′ 0″
D., L. & W. R. R.	12′ 2″	9′ 6″
Erie R. R.	12′ 6″	10′ 6″
Central R. R.	12′ 6″	10′ 0″
West Shore R. R.	12′ 0″	8′ 0″
Pennsylvania R. R. at Camden		8′ 6″
Pennsylvania & Reading R. R.		8′ 6″

(C) Overall Lengths:

The material to be transported is the most important factor controlling length. Overall lengths of existing motor trucks seldom exceed 24 feet. Overall lengths of tractors and semi-trailers seldom exceed 35 feet. Ladder wagons for fire department use sometimes attain lengths of 40 to 45 feet. Structural

TABLE A

MOST IMPORTANT AVERAGE DIMENSION OF TRUCKS

Capacity	Wheelbase	Extreme Length	Length, Back of Cab	Extreme Width in Inches	Height of Loading Platform in Inches Empty	Height of Loading Platform in Inches Loaded	Clearance in Inches
Type 1							
1	12 ft. 0 in.	16 ft. 0 in.	9 ft. 2 in.	68	36	32	9½
2	13 ft. 0 in.	17 ft. 0 in.	9 ft. 2 in	68	38	34	9½
3	13 ft. 6 in.	20 ft. 6 in.	11 ft. 0 in to 11 ft. 6 in.	87	42	38	10
4	14 ft. 6 in.	21 ft. 6 in.	12 ft. 0 in. to 12 ft. 6 in.	87	42	38	10
5	15 ft. 6 in.	22 ft. 6 in.	13 ft. 0 in. to 13 ft. 6 in.	87	44	38	10
7½	16 ft. 6 in.	23 ft. 6 in.	14 ft. 0 in. to 14 ft. 6 in.	87	44	38	10
Type 2							
3	11 ft. 6 in.	18 ft. 3 in.	12 ft. 6 in.	87	42	38	10
4	12 ft. 6 in.	30 ft. 3 in.	14 ft. 6 in.	87	42	38	10
5	13 ft. 6 in.	22 ft. 3 in.	16 ft. 6 in.	87	44	38	10
7½	14 ft. 0 in.	23 ft. 3 in.	17 ft. 6 in.	87	44	38	10
Type 3							
5	11 ft. 10½ in.	18 ft. 1 in.	14 ft. 0 in.	93½	46	40	7½
7	13 ft. 4½ in.	20 ft. 1 in.	16 ft. 0 in.	93½	46	40	7½
10	14 ft. 2½ in.	22 ft. 1 in.	18 ft. 0 in.	93½	46	40	7½
Power-dump							
5	11 ft. 9 in.	16 ft. 5 in.	8 ft. 3 in.	87	44	39	10½
Truck, Type 1							
7½	12 ft. 10 in.	17 ft. 5 in.	9 ft. 3 in.	87	44	39	10½

steel girders, telegraph poles, timbers and similar materials sometimes in excess of 60 feet are transported by tractors and semi-trailers. Tractor and trailer trains have attained lengths of over 80 feet, but are difficult to handle because the trailers "cut under" on turns.

Lengths are also controlled and restricted by the difficulties encountered in negotiating turns, particularly where roads are narrow and cross at acute angles and stationary objects, as posts, poles, pillars, trees, etc., are located in close proximity to the sides of the roads. It is, of course, obvious that wheelbase length is the most important factor that determines the turning radius of motor vehicles and that the radius increases as the length increases. Existing structures tend to restrict length by making negotiation difficult.

Modern truck garages, built to accommodate present vehicles, require posts which are spaced at least 16 feet 6 inches from the walls and 22 feet apart; this allows three trucks to be backed in between the posts and allows the front wheels of most trucks to project beyond the posts. Aisles about 25 feet wide provide turning space, which is usually sufficient for the trucks to be driven out from their positions. When a large number of trucks are stored, the difference in the sizes of small and large trucks allows this arrangement to be worked out with economy of space. These dimensions can be properly considered as of maximum average. Elevators of modern truck garages are made 24 feet long. Platform scales for weighing modern motor trucks are built to accommodate vehicles having a wheelbase length of 16 feet.

Trucks may be divided into three classes, according to the arrangement of the engine and the driver's seat.

1. This is the usual touring car type; the engine is over the front axle, the driver and control are behind the engine.

2. In this type the engine is over the front axle; the driver and control are directly above the engine.

3. The engine is over the front axle; the driver and control are on one side of the engine and the helper is on the other side.

Types 2 and 3 conserve the length of the chassis, as less space is taken for the driver's seat and control, thus allowing a longer loading platform in proportion to the wheelbase than type 1. The position of the operator's seat, whether back of or over the engine, usually affects the dimensions of length to a greater extent than the height. When the seat is placed back of the engine about 40 inches more frame length is required.

TABLE B

TURNING CIRCLES

Type	Capacity	Wheelbase	Diameter of Turning Circle in Feet
Type 1	1-ton	10 ft. 6 in.	47
		11 ft. 6 in.	53
		12 ft. 6 in.	55
Type 1	1½-ton	10 ft. 6 in.	47
		11 ft. 6 in.	53
		12 ft. 6 in.	55
		13 ft. 6 in.	60
Type 1	2-ton	10 ft. 6 in.	47
		11 ft. 6 in.	53
		12 ft. 6 in.	55
		13 ft. 6 in.	60
Type 1	3-ton	12 ft. 6 in.	55
		13 ft. 6 in.	59
		14 ft. 6 in.	61
Type 1	4-ton	12 ft. 6 in.	55
		13 ft. 6 in.	59
		14 ft. 6 in.	61
Type 1	5 ton	12 ft. 6 in.	57
		13 ft. 6 in.	62
		14 ft. 6 in.	68
Type 1	7½-ton	12 ft. 6 in.	57
		13 ft. 6 in.	62
		14 ft. 6 in.	68
		15 ft. 6 in.	71
Type 2	3-ton	11 ft. 0 in.	47
		11 ft. 6 in.	49
		12 ft. 0 in.	51
Type 2	5-ton	11 ft. 6 in.	53
Tractor	3-ton	10 ft. 4 in.	*40
Tractor	5-ton	10 ft. 8 in.	*41

Weights and Measures Useful in Truck Building.—These tables, which are reproduced from "Automotive Industries," will become more and more useful as the influence of the truck is extended and as it becomes necessary to draft fixed rate schedules for freight-carrying routes. But especially is the manufacturer interested in these items in advertising trucks for special purposes.

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* The trailer will usually cut under.

TABLE C

IMPORTANT DIMENSIONS AND TURNING RADII OF TYPE 1, TRUCKS AND TRACTORS

Tons Capacity	Wheelbase Inches	Width		Heights to Top of Cab Loaded		Length	Turning Radius in Feet	Length Back of Cab Inches
		Chain Drive	Worm Drive	Chain Drive	Worm Drive			
1	132	73¾	72¾	93¼	93⅝	205	22	108
1	144	73¾	72¾	93¼	93 11/16	217	25	120
1½	144	73¾	73¼	93 13/16	94⅜	217	25	120
1½	162	73¾	73¼	93 13/16	93⅜	241	29	144
2	144	73¾	73¼	94	94⅛	217	25	120
2	162	73¾	73¼	94	94⅛	241	29	144
3½ tractor	119	84⅜		98¼		180¾	*21	87
3½	156	84⅜		98 3/16		225¾	25	132
3½	168	84⅜		98⅛		249¾	26.3	156
3½	180	84⅜		98 1/16		273¾	26.6	180
5½ Tractor	119	90⅝		98⅜		180¾	*21	87
5½	156	90⅝		98 5/16		225¾	25	132
5½	168	90⅝		98¼		249¾	26.3	156
5½	180	90⅝		98 3/16		273¾	26.6	180
7½ Tractor	119	93		98⅝		180¾	*21	87
7½	156	93		98½		225¾	25	132
7½	168	93		98⅜		249¾	26.3	156
7½	180	93		98¼		273¾	26.6	180

BUILDING AND CONTRACTORS' MATERIAL

Asphaltum—87 lb. per cubic foot.

Brick—

Soft, 4.32 lb. each; 2.16 tons per 1000; size, 2¼ x 4 x 8¼ in.

Common, 5.4 lb. each; 2.7 tons per 1000; size, 2¼ x 4 x 8¼ in.

Hard, 6.48 lb. each; 3.24 tons per 1000; size, 2¼ x 4 x 8¼ in.

Cement—Portland, barrel weighs 380 lb.; equivalent to 4 bags.

Rosendale, barrel weighs 300 lb.; equivalent to 3 bags.

Western, barrel weighs 265 lb.; equivalent to 3 bags.

	Lb. per cu. ft.		Lb. per cu. ft.
Clay—Dry	63	Earth, loose	76
Wet	110	Gravel	95
Crushed Stone	100	Sand—Dry	97
Concrete	138	Wet	118
		Mortar, set	103

COAL AND COKE

Kind and Size	Weight per cu. ft.	No. cu. ft. per ton
Connellsville coke	26.30	76.04
Anthracite—Nut	56.88	35.16
Stove	56.33	35.50
Egg	56.07	35.69
Cannel	49.18	40.66
Bituminous—Illinois	47.22	42.35
Iowa lump	46.51	43.00
Indiana block	43.00	46.50
Pocahontas—Egg and lump	52.27	38.28
Pittsburgh	46.48	43.03
Charcoal—Hardwood	19	105.25
Pine	18	111.11

COTTON

Bale weighs 515 lb.; measures 27 x 27 x 54 in.; contains 23 cubic feet.

EGGS

In crates containing 30 doz., 53 lb.; crates measure 30 x 12 x 12 in. (10 lb.)

MILK

10-gal. can containing about 87 lb. of milk, weighs 115 lb.; can measures [illegible] in. high, 14 in. diameter.

Case of 12 quarts weighs 63 lb.; measures 18¼ x 14¼ x 12 in.; weight of case and empty bottles, 33 lb.

HAY

	Weight in.	Length in.	Width in.	Height in.
Hay—Standard bale	210	46	30	26
Small bale	120	43	24	18
Straw—Standard bale	180	46	30	26

To estimate the weight of hay in a mow or stack or a truck, allow 514 cubic feet for a ton.

SIZE OF BARRELS AND BASKETS

Bushel (U. S. Standard) equivalent to 4 pecks, 32 quarts, 64 pints; contains 1.2445 cubic feet, 2150.42 cubic inches. Average bushel basket measures 18½ inches top diameter; 11½ inches high.

Bushel crate measure measures.14 inches wide, 17½ inches long, 12¾ inches high.

BARREL

(U. S. Standard for vegetables, fruit and dry commodities, except cranberries.)

Capacity, 7056 cubic inches; 105 dry quarts; 3.281 bushels.

Head diameter, 17⅛ inches; bilge diameter, 20.37 inches; stave length, 27⅛ inches.

Capacity, 5826 cubic inches; 87 dry quarts; 2.709 bushels.

Head diameter, 16¼ inches; bilge diameter, 18.62 inches; stave length, 28½ inches.

FLOUR BARREL

Weighs 200-220 lb.; bilge diameter, 21 inches; head diameter, 18 inches; stave length, 28½; 28 lb. per cubic foot.

SUGAR BARREL

Weighs 300-360 lb.; bilge diameter, 25 inches; head diameter, 20½ inches; stave length, 30 inches.

SYRACUSE SALT BARREL

Weighs 280 lb.; bilge diameter, 21 inches; head diameter, 18 inches; stave length, 29 inches.

Syracuse Salt—Per bushel, 56 lb.; per cubic foot, 49 lb.

Turks Island Salt—Per bushel, 80 lb.

LIQUIDS

	Weight, lb. per gal.		Weight, lb. per gal.
Alcohol	6.75	Oil—Linseed	7.5
Gasoline	6.6	Lubricating	7.65
Kerosene	7.0	Vegetable	7.65
Molasses	12.5	Petroleum	8.0
Muriatic acid	9.62	Sulphuric acid	15.25
Nitric acid	11.7	Turpentine	7.2
Oil—Fuel	7.25	Vinegar	8.4
		Water	8.33

SNOW AND ICE

Snow—Fresh, 5-12 lb. per cubic foot. Wet, 15-50 lb. per cubic foot.
Ice, 57½ lb. per cubic foot.
Ice—(Standard block), 350 lb.; measures 11 x 22 x 44 inches.

MISCELLANEOUS COMMODITIES

	Pounds per cubic foot		Pounds per cubic foot
Ashes	42	Paper	58
Garbage	50	Rubber	59
Glass—Common	162	Rubber goods	94
Plate or crown	161	Saltpeter	69
Crystal	184	Starch	96
Flint	247	Street sweepings	31.5
Leather	59	Sulphur	125
Wool—Pressed	82		

ANGLES OF INCLINE NECESSARY TO DUMP COMMODITIES FROM STEEL-LINED BODIES

Material	Degrees	Material	Degrees
Ashes—Dry	33	Concrete	30
Wet	36	Earth—Loose	28
Brick	40	Compact	50
Clay	45	Garbage	30
Coal—Hard	23	Sand	35
Soft	30	Stone—Broken	27
Coke	23		

ROAD RESISTANCE

As measured by pull in pounds per ton

Over level, unsurfaced, concrete road	27.6
Concrete base, ⅛-inch skin top asphaltic oil and screenings	50.0
Water-bound macadam, level, good conditions	64.3
Concrete base, 1½-inch Topeka top, level, good conditions	68.5
Gravel road, level, good conditions	80.0
Earth road, level, fine dust, ¾ to 2 inches deep	99.3
Earth road, stiff mud on top, firm underneath, level	218.0
Loose gravel, new road, level, not packed down	263.0

NEWSPAPER

Rolls weigh 1,200 lb.; length, 72 inches; diameter, 32 inches.

553094 A

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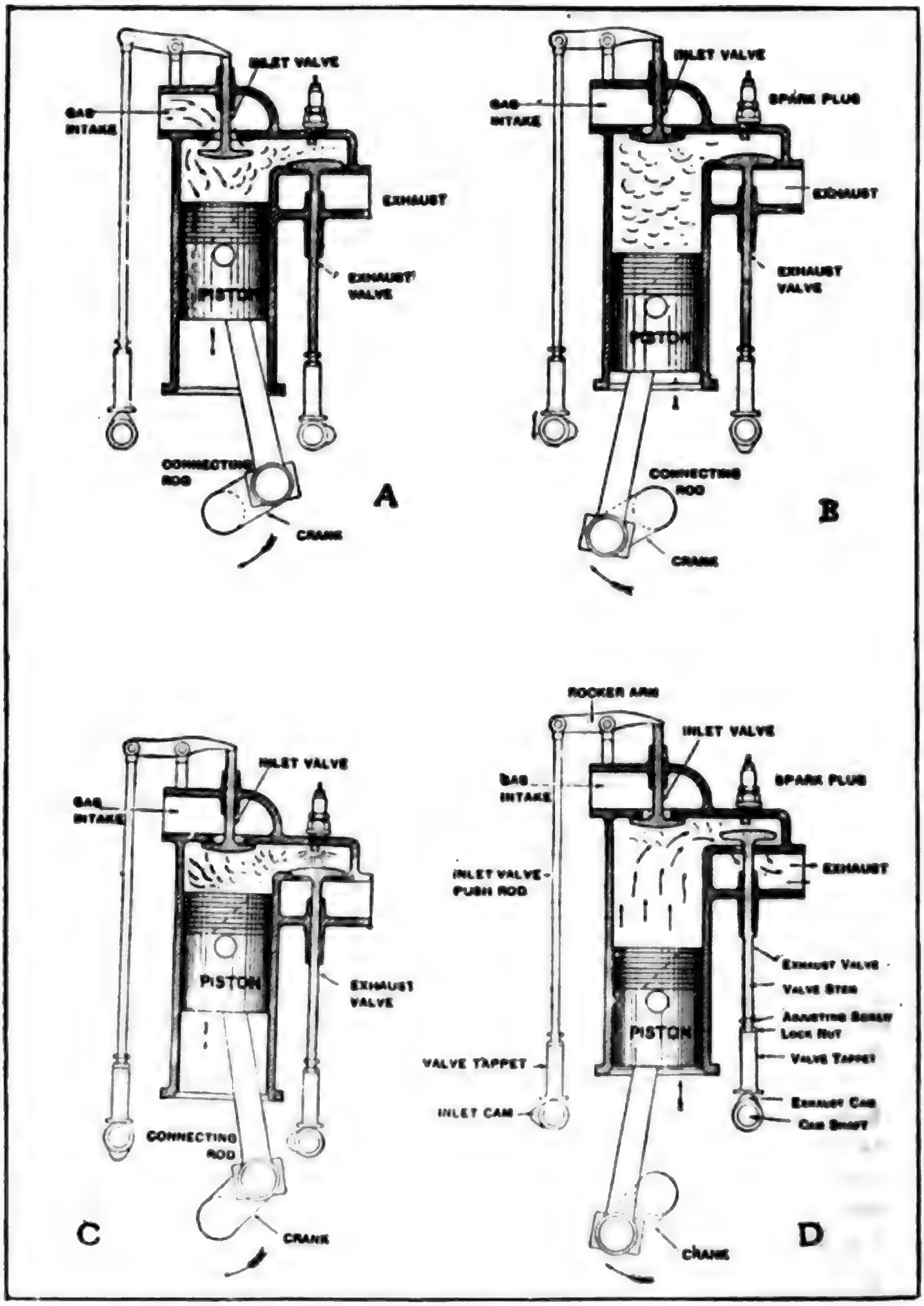

INLET VALVE
GAS INTAKE
EXHAUST
EXHAUST VALVE
PISTON
CONNECTING ROD
CRANK
A
INLET VALVE
GAS INTAKE
SPARK PLUG
EXHAUST
EXHAUST VALVE
PISTON
CONNECTING ROD
CRANK
B
INLET VALVE
GAS INTAKE
PISTON
EXHAUST VALVE
CONNECTING ROD
CRANK
C
ROCKER ARM
INLET VALVE
GAS INTAKE
SPARK PLUG
EXHAUST
INLET VALVE PUSH ROD
EXHAUST VALVE
VALVE STEM
ADJUSTING SCREW
LOCK NUT
VALVE TAPPET
VALVE TAPPET
INLET CAM
EXHAUST CAM
CAM SHAFT
PISTON
CRANK
D

Fig. 43.—Simple Diagrams Showing the Various Cycles of Operation Necessary to Obtain an Explosion in the Four-Stroke Gasoline Engine Cylinder. A—Suction. B—Compression. C—Explosion. D—Exhaust.

CHAPTER II

THE MOTOR TRUCK POWER PLANT

The Four-Cycle Engine and Its Operation—How to Secure Steady Power—Two-, Four-, and Six-Cylinder Engines—Actual Duration of Cycle Phases—Main Parts of Engines and Their Functions—Operating Conditions With Truck Motors—Horse Power Formulas—The Ford Power Plant—Typical Motor Truck Engines—The Auto Car—The Packard—The Dodge—Wisconsin Engines—Nash Buda Motor—Buda Model HTU—Hercules—White Motors—International Model E—International Model G—Riker—Mack A. C.—Power Plant Installation.

Engine Design for Modern Gasoline Trucks.—In the early days of motor truck development there was considerable diversity in internal combustion engine forms that were applied to motor truck propulsion. Engines operating on both the two-cycle and four-cycle principles were used and cooling by air was found on a number of the early models. Some of the well-known truck makers of today had unconventional power plants in their early models, such as a two-cylinder two-cycle air-cooled motor and three-cylinder two-cycle air cooled. Several trucks had large double opposed cylinder motors operating on the four-cycle principle, disposed under the truck body. One truck that was made in fairly large quantities and that was operated by a number of firms in fairly large fleets was provided with a large two-cylinder air-cooled engine that extended almost from the front to the rear of the chassis.

At the present time, practically all truck makers favor the four-cylinder, four-cycle, water-cooled power plant. The difference between a two-cycle engine, which is widely used in marine work, and a four-cycle, which is the type universally applied to automobiles, is that in the former one obtains an explosion for each two strokes of the piston, while in the latter it requires four strokes of the piston to complete a cycle of operations. The two-cycle engine is simpler in construction, as there are no valves above the piston, the gases being taken in and discharged through ports in the cylinder walls, which are opened and closed by the movement of the piston. As this type is not used in motor trucks, only the four-cycle form will be explained.

Four-Cycle Engine Operation.—Considering the view shown at Fig. 43, A, the first necessary operation is charging the cylinder with explosive material. The piston is at the top of its stroke and it moves toward the open end of the cylinder. The engine works as a pump, and the piston draws in a charge of combustible gas through the open intake valve, which is in connection with the vaporizer which furnishes the gas. While all inlet valves are operated mechanically at the present time, some of the early types were provided with automatic inlet valves. An automatic valve opens because of a light vacuum or suction existing when the piston has traveled down a certain portion of its stroke, and then the outside air pressure is greater than that in the cylinder. The external air pressure is greater than the tension of the spring, which tends to keep the valve closed, and the member is therefore drawn from its seat by the piston. At the end of the intake stroke and after the cylinder has filled with gas the pressure inside and outside is the same and the valve spring closes the intake valve. As the exhaust valve spring is very strong, this member has not been lifted from its seat by the difference in pressure. The exhaust valve is opened by mechanical means solely and lifts only when operated by the cam and push-rod mechanism. In modern engines the valves are usually the same size and operated by the same form of mechanism.

The condition in the cylinder of the gas engine after the piston has reached the bottom of its stroke is very much the same as that which obtains in a gun of the muzzle-loading type after the explosive charge has been introduced. We have learned that to obtain power from gunpowder it is necessary to ram it firmly in the combustion chamber of the gun. The gasoline gas which has been taken into the engine cylinder must also be compressed before it is ignited in order to obtain power. It is compacted into one-quarter or one-fifth of its former volume, and whereas its pressure is about fifteen pounds per square inch before it is compacted, at the end of the compression stroke of the piston the pressure will be increased to sixty, and even seventy-five pounds per square inch. At the end of this compression stroke, the start of which is shown at B, the conditions in the engine cylinder are the same as those which prevail in the barrel of the cannon after the powder has been tightly rammed in the closed end of the gun barrel and the ball is forced in on top of it. The compressed gas in the engine cylinder is exploded electrically by a spark occurring between the points of the spark plug, as shown at C. Just as the explosion in the cannon drives out the ball, that in the engine cylinder forces the piston out and causes the crankshaft and flywheel attached to it to revolve. The flywheel stores power to carry the crankshaft through the charging, compression and exhaust strokes in a single-cylinder engine.

In order to obtain a perfectly tight combustion chamber, both intake and exhaust valves are closed, as shown at C, before the gas is ignited, because all of the pressure produced by the exploding gas is to be directed against the top of the movable piston. When the piston reaches the bottom of its power stroke, as indicated at D, the exhaust valve is lifted by means of the valve tappet which is raised because of the point or lift on the cam. The cam shaft is driven by positive gearing and revolves at half the engine speed. The exhaust valve remains open during the whole of the return stroke of the piston, and as this member moves toward the closed end of the cylinder it forces out burned gases ahead of it, through the passage controlled by the exhaust valve. The cam shaft is revolved at half the engine speed because the exhaust valve is raised from its seat during only one stroke out of four, or only once every two revolutions of the crankshaft. Obviously, if the cam was turned at the same speed as the crankshaft it would remain open once every revolution, whereas the burned gases are expelled only once in two turns of the crankshaft. The operation of the valves when they are placed so they open directly into the cylinder is shown at Fig. 44.

It will be evident that three strokes of the piston in any one cylinder are necessary to secure one useful explosion, just as practically three operations are needed to fire the cannon. The first downward movement of the piston fills the cylinder with gas and is known as the "intake stroke." This is accomplished during the first half revolution of the crankshaft. The return movement of the piston is accomplished during the second half of the first revolution and compresses the gas previously sucked in. This is called the "compression stroke." The expansive force back of the piston produced by the explosion forces the

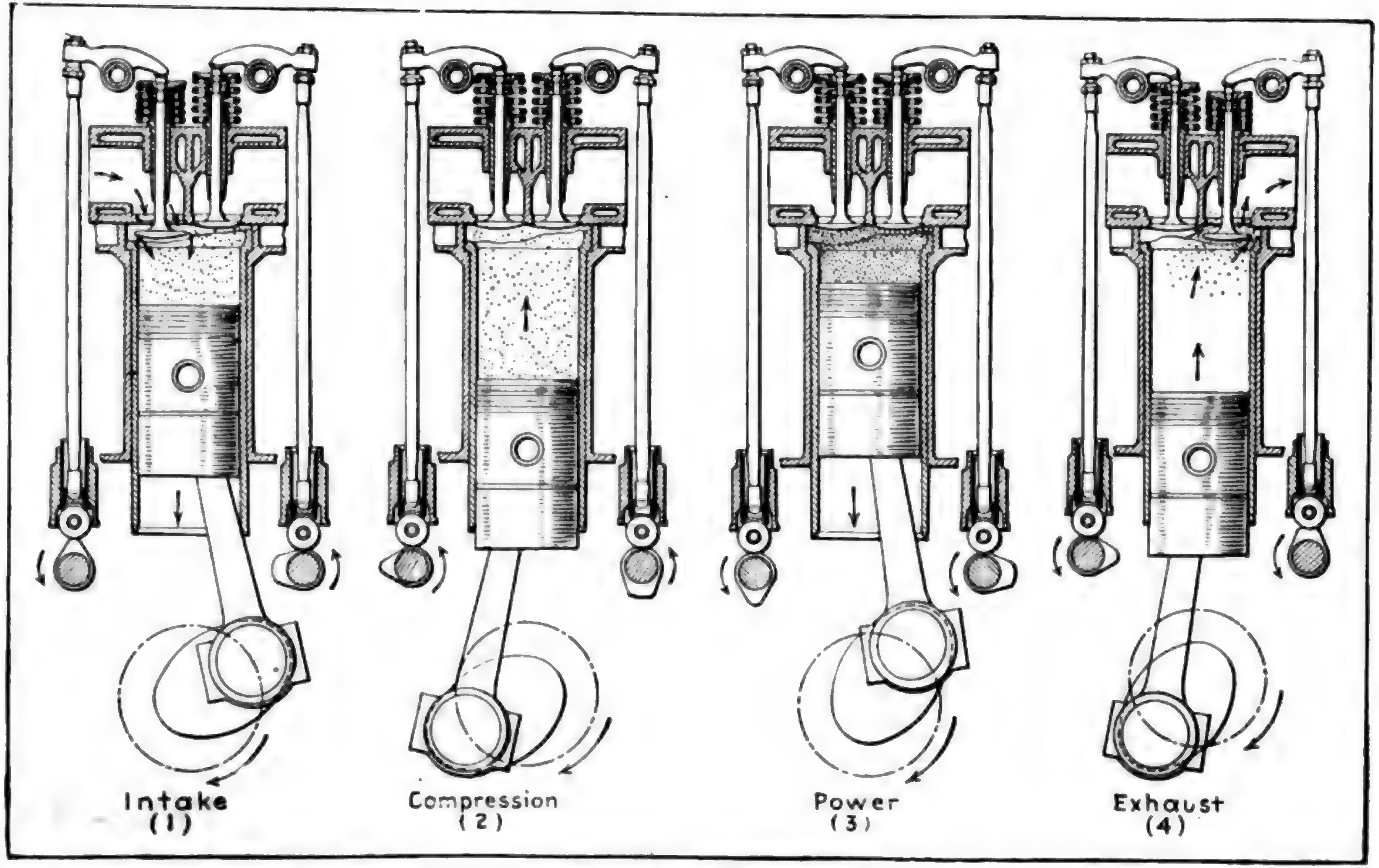


Fig. 44.—Diagram Showing Sequence of Cycles in Simplified Overhead Valve-Type Internal Combustion Engine. Gas Which Enters on the Intake Stroke is Compressed on the Next Upward Stroke of the Piston, is Exploded at the End of the Compression Stroke and then Drives the Piston Down Imparting Power to the Crankshaft. The Burnt Gases are then Expelled from the Cylinder Through the Exhaust Valve.

piston down again, this turning the crankshaft through the first half of the second revolution, which is known as the "power stroke." The last half of the second revolution produces a return movement of the piston toward the closed end, and as the burned gases are expelled and the cylinder is cleared to receive the fresh charge, this movement of the piston is known as the "exhaust stroke." The cycle of operations described is continued and repeats as long as the cylinder is supplied with fuel, the spark takes place to fire the gas and the engine parts are

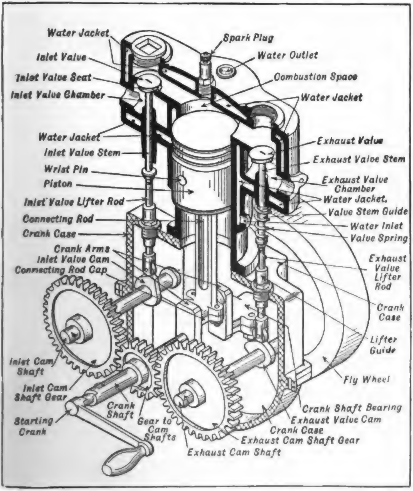

Water Jacket
Inlet Valve
Inlet Valve Seat
Inlet Valve Chamber
Water Jacket
Inlet Valve Stem
Wrist Pin
Piston
Inlet Valve Lifter Rod
Connecting Rod
Crank Case
Crank Arms
Inlet Valve Cam
Connecting Rod Cap
Inlet Cam Shaft
Inlet Cam Shaft Gear
Starting Crank
Crank Shaft
Gear to Cam Shafts
Exhaust Cam Shaft
Spark Plug
Water Outlet
Combustion Space
Water Jacket
Exhaust Valve
Exhaust Valve Stem
Exhaust Valve Chamber
Water Jacket
Valve Stem Guide
Water Inlet
Valve Spring
Exhaust Valve Lifter Rod
Crank Case
Lifter Guide
Fly Wheel
Crank Shaft Bearing
Exhaust Valve Cam
Crank Case
Exhaust Cam Shaft Gear

Fig. 45.—Diagram Showing Principal Parts of Single-Cylinder Water-Cooled T Head Power Plant.

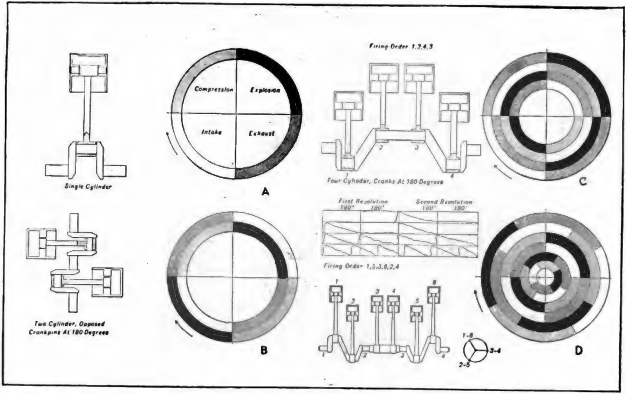

Single Cylinder
Compression
Explosion
Intake
Exhaust
A
Firing Order 1,2,4,3
1
2
3
4
Four Cylinder, Cranks At 180 Degrees
C
Two Cylinder, Opposed
Crankpins At 180 Degrees
B
First Revolution
180°
180°
Second Revolution
180°
180°
Firing Order 1,5,3,6,2,4
1
2
3
4
5
6
1
2
3
4
1-6
3-4
2-5
D

Fig. 46.—Diagram Showing Sequence of Explosions in One, Two, Four and Six-Cylinder Automobile Engines.

prevented from binding by means of lubrication between all moving parts and cooling those portions liable to become excessively hot by suitable extraneous means which prevents overheating. A part sectional view of a simple engine is given at Fig. 45 to show the parts needed in an internal combustion power plant.

How to Secure Steady Power.—Referring to Fig. 46, A, the sequence of operation in a single-cylinder motor can be easily understood. Assuming that the crankshaft is turning in the direction of the arrow, it will be seen that the intake stroke comes first, then the compression, which is followed by the power impulse, and lastly the exhaust stroke. If two cylinders are used, it is possible to balance the explosions in such a way that one will occur each revolution. While cylinder No. 1 is taking in a fresh charge of gas, cylinder No. 2 is exploding. When cylinder No. 1 is compressing, cylinder No. 2 is exhausting. During the time that the charge in cylinder No. 1 is exploded, cylinder No. 2 is being filled with fresh gas. While the exhaust gases are being discharged from cylinder No. 1, cylinder No. 2 is compressing the gas previously taken in. With the crankshaft arrangement shown at Fig. 46 the explosions are spaced equidistant.

Using four or more cylinders conduces to steady power generation and a lessening of vibration. Most modern trucks employ four-cylinder engines because a power impulse may be secured twice every revolution of the crankshaft, or a total of four-power strokes during two revolutions. The parts are so arranged that while the charge of gas in one cylinder is exploding, those which come next in firing order are compressing, discharging the inert gases and drawing in a fresh charge, respectively. When the power stroke is completed in one cylinder, the piston in that member in which a charge of gas has just been compressed has reached the top of its stroke and when the gas is exploded the piston is reciprocated and keeps the crankshaft turning. When a four-cylinder engine is used, the fly wheel is much lighter than that of a single-cylinder form. In fact, many modern four-cylinder engines developing thirty horsepower weigh less than the early single-cylinder forms, which developed but one-fourth that amount of energy. The way the explosions and other parts of the cycle of operations occurs is clearly shown at Fig. 46, C.

In the four-cylinder engine operation just described it will be seen that the power strokes follow each other without loss of time, and one cylinder begins to fire and the piston moves down just as soon as the member ahead of it has completed its power stroke. In a four-cylinder motor, the crankpins are placed at 180 degrees, or on the halves of the crank circle. The crankpins for cylinders No. 1 and No. 4 are on the same plane, while those for cylinders No. 2 and No. 3 also move in unison. The diagram describing sequence of operations in each cylinder is based on a firing order of one, two, four, three. The outer circle, as in previous instances, represents the cycles of operations in cylinder one. The next one toward the center, cylinder No. 2, the third circle represents the sequence of events in cylinder No. 3, while the inner circle outlines the strokes in cylinder four. The various cylinders are working as follows:

1	2	3	4
Explosion	Compression	Exhaust	Intake
Exhaust	Explosion	Intake	Compression
Intake	Exhaust	Compression	Explosion
Compression	Intake	Explosion	Exhaust

The six-cylinder type of motor, the action of which is shown at Fig. 46, D, is superior to the four-cylinder inasmuch as the power strokes overlap, and instead of having two explosions each revolution we have three explosions. The conventional crankshaft arrangement in a six-cylinder engine is just the same as though one used two three-cylinder shafts fastened together so pistons 1 and 6 are on the same plane, as are pistons 2 and 5. Pistons 3 and 4 also travel together. With the cranks arranged as outlined at Fig. 46, D, the firing order is one, five, three, six, two and four. The manner in which the power strokes overlap is clearly shown in the diagram. An interesting comparison is also made in the small diagram in the upper left-hand corner of this view.

Two, Four and Six-Cylinder Engines.—A rectangle is divided into four columns; each of these corresponds to 180 degrees, or half a revolution. Thus the first revolution of the crankshaft is represented by the first two columns, while the second revolution is represented by the last two. Taking the portion of the diagram which shows the power impulse in a one-cylinder engine, we see that during the first revolution there has been no power impulse. During the first half of the second revolution, however, an explosion takes place and a power impulse is obtained. The last portion of the second revolution is devoted to exhausting the burned gases, so that there are three idle strokes and but one power stroke.

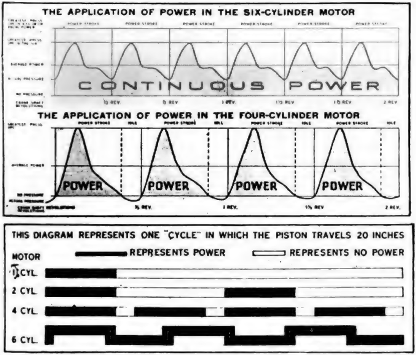

THE APPLICATION OF POWER IN THE SIX-CYLINDER MOTOR
POWER STROKE
POWER STROKE
POWER STROKE
POWER STROKE
POWER STROKE
POWER STROKE
AVERAGE POWER
NO PRESSURE
CONTINUOUS POWER
½ REV.
1 REV.
1½ REV.
2 REV.
THE APPLICATION OF POWER IN THE FOUR-CYLINDER MOTOR
POWER STROKE
IDLE
POWER STROKE
IDLE
POWER STROKE
IDLE
POWER STROKE
IDLE
AVERAGE POWER
NO PRESSURE
POWER
POWER
POWER
POWER
½ REV.
1 REV.
1½ REV.
2 REV.
THIS DIAGRAM REPRESENTS ONE "CYCLE" IN WHICH THE PISTON TRAVELS 20 INCHES
MOTOR
REPRESENTS POWER
REPRESENTS NO POWER
1 CYL.
2 CYL.
4 CYL.
6 CYL.

Fig. 47.—Diagrams Outlining Advantages of Multiple Cylinder Motors and Showing That They Deliver Power More Evenly Than Single-Cylinder Types.

The effect when two cylinders are employed is shown immediately below. Here we have one explosion during the first half of the first revolution in one cylinder and another during the first half of the second revolution in the other cylinder. With a four-cylinder engine there is an explosion each half revolution, while in a six-cylinder engine there is one and one-half explosions during each half revolution. When six cylinders are used there is no lapse of time between power impulses, as these overlap and a continuous and smooth-turning movement is imparted to the crankshaft. This point is also brought out in the diagrams at Fig. 47. While the six-cylinder has many advantages for passenger car use, the simplicity of the four-cylinder and the fact that it runs smoothly enough for all practical purposes makes it the ideal and popular form for motor truck use.

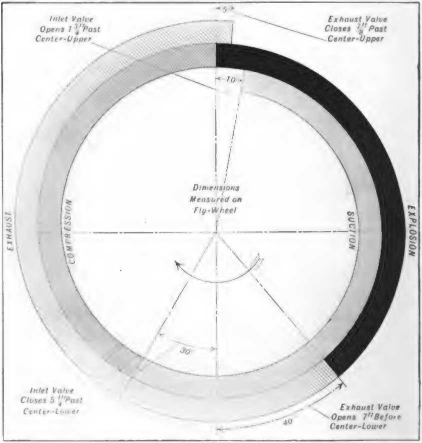

5
Inlet Valve Opens $1\frac{3}{4}''$ Past Center-Upper
Exhaust Valve Closes $\frac{7}{8}''$ Past Center-Upper
10
Dimensions Measured on Fly-Wheel
EXHAUST
COMPRESSION
SUCTION
EXPLOSION
30
Inlet Valve Closes $5\frac{1}{4}''$ Past Center-Lower
Exhaust Valve Opens 7'' Before Center-Lower
40

Fig. 48.—Diagram Showing Actual Duration of Different Cycle Functions as Measured in Degrees of Crankshaft Travel.

Actual Duration of Cycle Phases.—In the diagram represented at Fig. 46, the writer has assumed, for the sake of simplicity, that each stroke takes place during half of one revolution of the crankshaft, which corresponds to a crankpin travel of 180 degrees. The actual duration of these strokes is somewhat different. For example, the inlet stroke is usually a trifle more than a half revolution, and the exhaust is always considerably more. The diagram showing the comparative duration of the strokes is shown at Fig. 48. The inlet valve opens ten degrees after the piston starts to go down and remains open thirty degrees after the piston has reached the bottom of its stroke. This means that the engine intake stroke corresponds to a crankpin travel of 200 degrees, while the compression stroke is measured by a movement of but 150 degrees. It is common practice to open the exhaust valve before the piston reaches the end of the power stroke, so that the actual duration of the power stroke is about 140 degrees, while the exhaust stroke corresponds to a crankpin travel of 225 degrees. In this diagram, which represents proper time for the valves to open and close, the dimensions in inches given are measured on the fly wheel and apply only to a certain motor. If the flywheel were smaller ten degrees would take up less than the dimensions given, while if the fly wheel was larger a greater space on its circumference would represent the same crankpin travel. Each engine designer times

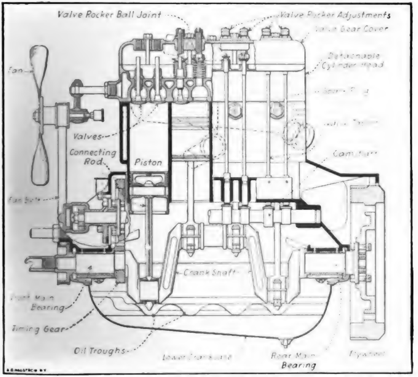

Valve Rocker Ball Joint
Valve Rocker Adjustments
Valve Gear Cover
Fan
Detachable Cylinder Head
Spark Plug
Valve Tappets
Valves
Connecting Rod
Piston
Camshaft
Fan Belt
Crank Shaft
Front Main Bearing
Timing Gear
Oil Troughs
Lower Crankcase
Rear Main Bearing
Flywheel

Fig. 49.—Sectional View of Typical Overhead Valve. Cylinder High-Speed Engine.

his valves differently, and there are many factors that control the timing, such as the size and lift of the valves, their location in the cylinder head and the speed of rotation one expects the engine to attain. A typical high speed overhead valve four-cylinder engine is shown at Fig. 49 and an L head six-cylinder engine in which the valves are carried in a pocket at the side of the cylinder is depicted at Fig. 50. If the valves and cylinder dimensions were the same size, those in the L head cylinder would have to be timed differently, because the gas does not have as free flow in or out as in the other construction.

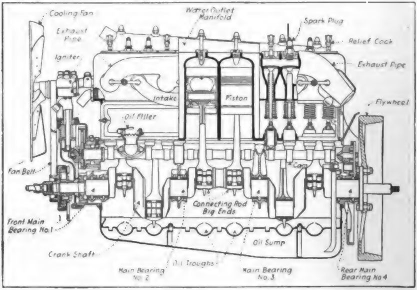

Cooling Fan
Exhaust Pipe
Igniter
Water Outlet Manifold
Spark Plug
Relief Cock
Exhaust Pipe
Intake
Piston
Oil Filler
Flywheel
Fan Belt
Cam
Connecting Rod Big Ends
Front Main Bearing No.1
Oil Sump
Crank Shaft
Oil Troughs
Main Bearing No. 2
Main Bearing No. 3
Rear Main Bearing No.4

Fig. 50.—Part Sectional View of Studebaker Six-Cylinder Engine Showing Cylinder and Cylinder Head Cast Integral, also Four-Bearing Crankshaft. This Type is Very Popular in Passenger Car Practice.

Main Parts of Engine.—The principal elements of a gas engine are not difficult to understand and their functions are easily defined. In place of a barrel of the gun, one has a smoothly machined water-jacketed cylinder in which a smaller cylindrical or barrel-shaped element fitting the bore closely may be likened to a bullet or cannon ball. It differs in this important respect, however, as while the shot is discharged from the mouth of the cannon as a result of the explosion, the piston member sliding inside of the main cylinder cannot leave it, as its movements back and forth from the open to the closed end and back again are limited by simple mechanical connection or linkage which comprises crank and connection rod. It is by this means that the reciprocating movement of the piston is transformed into a rotary motion of the crankshaft.

The fly wheel is a heavy member attached to the crankshaft which has energy stored in its rim as the member revolves, and the momentum of this revolving mass tends to equalize the intermittent pushes on the piston head produced by the explosion of the gas in the cylinder. If some explosive is placed in the chamber formed by the piston and closed end of the cylinder and exploded, the piston would be the only part that would yield to the pressure which would produce a downward movement. As this is forced down, the crankshaft is turned by the connecting rod, and as this part is hinged at both ends it is free to oscillate as the crank turns, and thus the piston may slide back and forth while the crankshaft is rotating or describing a curvilinear path. The treadle mechanism of a sewing machine and the connecting rod to drive the power wheel illustrate clearly how a reciprocating motion can be changed to a rotary one.

In addition to the simple elements described, it is evident that a gasoline engine must have other parts. The most important of these are the valves, of which there are two to each cylinder. One closes the passage connecting to the gas supply and opens during one stroke of the piston in order to let the explosive gas into the combustion chamber. The other member, or exhaust valve, serves as a cover for the opening through which the burned gases can leave the cylinder after their work is done. The spark plug is a simple device which may be compared to the fuse or percussion cap of the cannon. It permits one to produce an electric spark in the cylinder when the piston is at the best point to utilize the pressure which obtains when the compressed gas is fired. The valves are open one at a time, the inlet valve being lifted from its seat while the cylinder is filling and the exhaust valve is opened when the cylinder is being cleared. They are normally kept seated by means of compression springs.

The cams raise the valves by suitable plungers which are guided by special bearings. The piston is provided with packing rings to prevent leakage of gas. The cam shafts are driven by gears meshing with a driving member on the engine crankshaft, as shown at Figs. 52 and 53. A piston and connecting rod are shown as they appear separated at Fig. 54, while the method

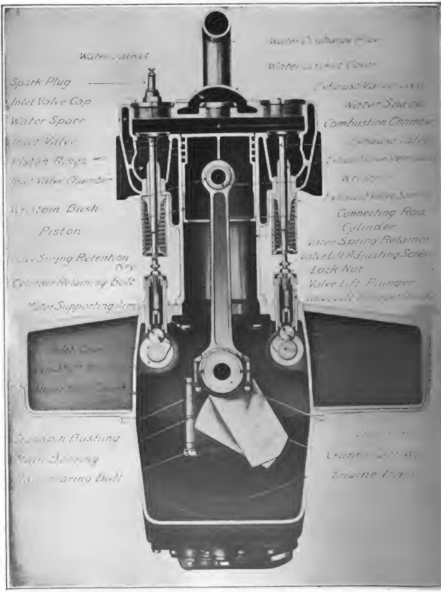

Water Jacket
Spark Plug
Inlet Valve Cap
Water Space
Inlet Valve
Piston Rings
Inlet Valve Chamber
Piston
Valve Spring Retention
Water Supporting Arm
Water Discharge Pipe
Water Jacket Cover
Exhaust Valve Cap
Water Space
Combustion Chamber
Exhaust Valve
Connecting Rod
Cylinder
Valve Spring Retainer
Valve Lift Adjusting Screw
Lock Nut
Valve Lift Plunger
Bushing
Engine Base

Fig. 51.—End Sectional View of Typical T Head Internal Combustion Motor.

of removing a rod and piston from the engine assembly by taking off the connecting rod cap and releasing the crankshaft is also shown clearly in this view.

The crankshaft is supported by the top half of a two-piece crank case, bearings being provided so the shaft can rotate freely and yet without noise or lost motion. The lower half of the crankcase serves as an oil container in most engines. The upper half of the case also carries the cylinders, these members being attached by secure fastenings such as bolts. The shaft or shafts carrying the cams actuating the valves are also carried by the top half of the engine base and revolve in suitable bearings therein. The pipe that carries the fresh gas mixture from the carburetor to the inlet valve chambers is known as the inlet or intake manifold; that taking the exhaust gases from the cylinders to the muffler is known as the exhaust manifold.

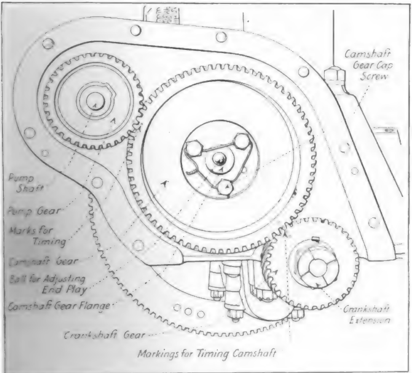

Camshaft Gear Cap Screw
Pump Shaft
Pump Gear
Marks for Timing
Camshaft Gear
Ball for Adjusting End Play
Camshaft Gear Flange
Crankshaft Gear
Crankshaft Extension
Markings for Timing Camshaft

Fig. 52.—Front View of Engine Base with Cover Removed Showing Camshaft Driving Gears and Method of Marking the Teeth to Insure Correct Reassembly if Engine is Dismantled.

All engines have other parts attached that belong to the cooling system, such as the water pump and fan. The magneto belongs to the ignition system. The engine oiling parts are also included in the engine mechanism. The way these various parts differ in detail will be explained in the descriptions of typical truck engines which follow, and a good idea of the diversity of design may be obtained by studying the clear illustrations of conventional engine forms.

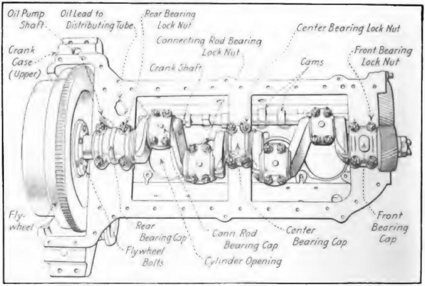

Oil Pump Shaft
Oil Lead to Distributing Tube
Rear Bearing Lock Nut
Center Bearing Lock Nut
Connecting Rod Bearing Lock Nut
Crank Case (Upper)
Front Bearing Lock Nut
Cams
Crank Shaft
Fly-wheel
Front Bearing Cap
Rear Bearing Cap
Conn. Rod Bearing Cap
Center Bearing Cap
Flywheel Bolts
Cylinder Opening

Fig. 53.—The Bottom View of Typical Motor Truck Engine with Lower Half of Crank Case Removed Showing Important Parts.

Operating Conditions of Truck Motors.—Authorities state that the power plant of a motor truck will have a piston speed of two or three times that of a similar engine used for passenger car propulsion because of the low reduction gear ratios necessary to drive a heavy truck with an engine of reasonable piston displacement. A truck engine operates under heavy duty conditions practically all of the time, and it should be specially built for the work. All bearing surfaces should be larger than in a pleasure car motor of the same power, the lubrication system must be positive, and the water cooling is usually by forced circulation in which a pump keeps the water moving. An interesting comparison may be made between a truck and passenger car engine of 300 cubic inches piston displacement to show how truck engines must be run faster. A passenger car with 4.25 to

1 reduction and 34-inch tires will require an engine speed of 750 r.p.m. to attain a vehicle speed of 15 miles per hour. A two-ton truck with 36-inch tires and 8.5 to 1 drive axle reduction would necessitate an engine speed of about 1,400 r.p.m., or 650 r.p.m. more than the pleasure car to attain the same speed. Unless specially designed for high speed work, the normal crankshaft speed of a motor truck power plant should not exceed 1,000 r.p.m. to secure long life of bearings and other engine parts.

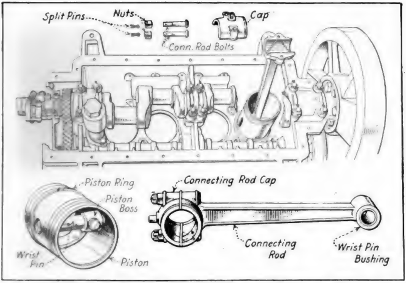

Split Pins
Nuts
Cap
Conn. Rod Bolts
Piston Ring
Piston Boss
Wrist Pin
Piston
Connecting Rod Cap
Connecting Rod
Wrist Pin Bushing

Fig. 54.—Diagram Showing Construction of Piston and Connecting Rod of I. H. C. Engine.

Horsepower Formulæ.—The horsepower of a motor truck engine can be computed by a number of different methods. Some of them are very scientific for exact results; others permit of a sufficiently close practical approximation for everyday use. Some of the simple empirical formulæ follow:

Authority	Formula
S. A. E. Royal Auto Club	$\frac{D^2N}{2.5} = \text{H.P.}$
Brit. Inst. of Auto Engrs.	$0.45\ (D+L)\ (D-1.18) = \text{H.P.}$
E. P. Roberts	$\frac{D^2LRN}{18{,}000} = \text{H.P.}$

D = Diam. of cylinder in inches. R = Rev. per min. of crankshaft
L = Length of stroke in inches. N = Number of cylinders.

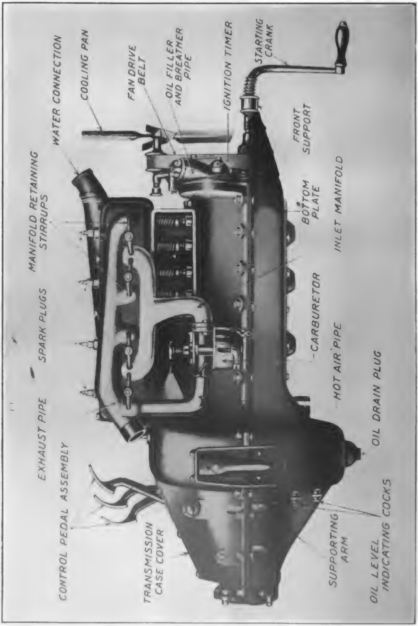

CONTROL PEDAL ASSEMBLY
EXHAUST PIPE
SPARK PLUGS
MANIFOLD RETAINING STIRRUPS
WATER CONNECTION
COOLING PAN
FAN DRIVE BELT
OIL FILLER AND BREATHER PIPE
IGNITION TIMER
STARTING CRANK
TRANSMISSION CASE COVER
SUPPORTING ARM
OIL LEVEL INDICATING COCKS
OIL DRAIN PLUG
HOT AIR PIPE
CARBURETOR
INLET MANIFOLD
BOTTOM PLATE
FRONT SUPPORT

Fig. 55.—Valve Side of the Ford Model T Unit Power Plant Showing Manifolds, Carburetors and

Derivation of the S. A. E. Horsepower Formula.—The indicated horsepower of a single-cylinder, four-cycle engine is equal to one-quarter times the mean effective pressure P, acting throughout the working stroke, times the area of the piston A, in square inches, times the piston speed S divided by 33,000, thus:

$$\text{I. H. P.} = \frac{1}{4}\,\frac{\text{P A S}}{33{,}000}$$

Multiplying this by the number of cylinders N gives the I.H.P. for an engine of the given number of cylinders, and further multiplying the mechanical efficiency of the engine E gives the brake horsepower. Therefore the complete equation for B.H.P. reads:

$$\text{B. H. P.} = \frac{\text{P A S N E}}{33{,}000 \times 4}$$

The S.A.E. assumed that all motor car engines will deliver or should deliver their rated power at a piston speed of 1,000 feet per minute, that the mean effective pressure in such engine cylinders will average 90 pounds per square inch, and that the mechanical efficiency will average 75 per cent.

Substituting these values in the above B.H.P. equation, and substituting for A its equivalent, .7854 D^2, the equation reads:

$$\text{B. H. P.} = \frac{90 \times .7854 \quad D^2 \times 1{,}000 \times N \times .75}{33{,}000 \times 4}$$

and combining the numerical values it reduces to:

$$\text{B. H. P.} = \frac{D^2N}{2.489}$$

or, in round numbers, with a denominator 2.5.

The Ford Power Plant.—The motive power of the Ford car consists of what is known as a "unit power plant," incorporating the engine or power-producing member and the change speed gearing and clutch or power transmitting member. A side view

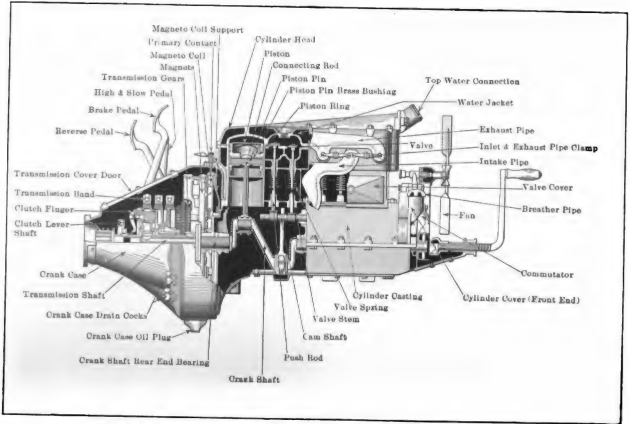

Magneto Coil Support
Primary Contact
Magneto Coil
Magnets
Transmission Gears
High & Slow Pedal
Brake Pedal
Reverse Pedal
Transmission Cover Door
Transmission Band
Clutch Finger
Clutch Lever Shaft
Crank Case
Transmission Shaft
Crank Case Drain Cocks
Crank Case Oil Plug
Crank Shaft Rear End Bearing
Crank Shaft
Cylinder Head
Piston
Connecting Rod
Piston Pin
Piston Pin Brass Bushing
Piston Ring
Top Water Connection
Water Jacket
Exhaust Pipe
Valve
Inlet & Exhaust Pipe Clamp
Intake Pipe
Valve Cover
Breather Pipe
Fan
Commutator
Cylinder Cover (Front End)
Cylinder Casting
Valve Spring
Valve Stem
Cam Shaft
Push Rod

Fig. 56.—Part Sectional View of Ford Four-Cylinder Unit Power Plant.

of the engine is shown at Fig. 55, this showing clearly the parts that are readily discernible from the outside. The engine is a four-cylinder type, having the cylinders cast in one block which is integral with the top half of the engine crank case. As all the valves are on one side of the cylinder, it is known as an "L block" construction. The bore of the cylinder is 3¾ inches, the stroke of the piston is 4 inches. The engine is capable of attaining high rotative speed and will develop well over 20 horsepower.

The advantage of including the change speed gearing and clutch in a unit with the engine is that there is no danger of loss of alignment of these members due to frame distortion as is possible when the power-producing and transmission elements are separate units, each having its independent means of support. The parts of the Ford power plant assembly are lined up properly when the engine is built, and there is no possibility of loss of this alignment due to frame distortion or deflection. The parts of the engine and the distinctive two speed and reverse planetary transmission used in this power plant are clearly shown at Fig. 56. The Ford engine was not originally designed for truck use, but thousands are in use for that purpose in converted Ford passenger cars and in the light one-ton truck marketed by the Ford interests. It is a simple and reliable motor and can stand lots of punishment despite its light construction. Of course, it does not compare with the heavier, specially designed truck motors to be described in either endurance or freedom from trouble. It will give good service if properly handled and taken care of.

Typical Motor Truck Power Plants.—In essentials the engines used on practically all motor trucks do not vary much in construction, but if one studies the details, it will be evident that power plant designers have many different ideas for mechanism to accomplish the same object. Some will cast the cylinders in pairs, others will have the four cylinders in one casting. In some power plants the cylinder head is removable to provide access to the valves and combustion chamber for removing carbon, while in others the cylinder head is an integral casting with the cylinder and the entire cylinder assembly must be removed to gain access to the pistons and other interior parts.

Autocar Two-Cylinder Engine.—The only two-cylinder engine used on a truck of American manufacture is shown at Figs. 57 and 58, which depict the power plant of the Autocar truck. This

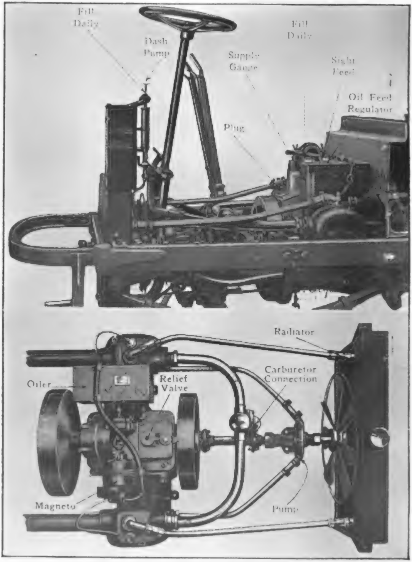

Fill Daily
Dash Pump
Supply Gauge
Fill Daily
Sight Feed
Oil Feed Regulator
Plug
Radiator
Carburetor Connection
Oiler
Relief Valve
Magneto
Pump

Fig. 57.—View Showing Construction of the Autocar Double Opposed Horizontal Cylinder Motor. Also Its Installation in the Truck Chassis.

engine has a bore of 4¾ inches and a stroke of 4½ inches. Following the only practical construction possible with an opposed motor the cylinders are individual castings and are bolted on opposite sides of the engine crankcase. The crankshaft has two throws, spaced 180 degrees apart, and revolves on large single

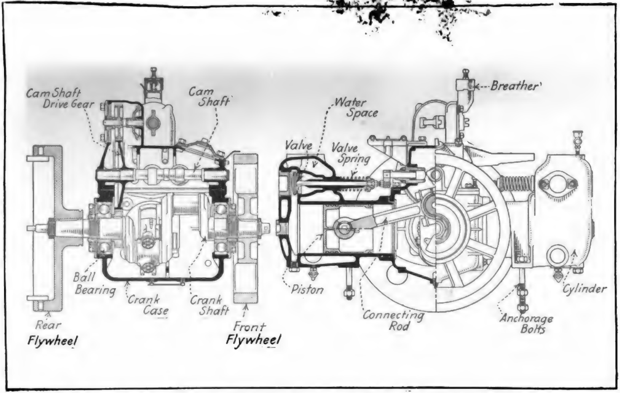

Cam Shaft Drive Gear
Cam Shaft
Water Space
Breather
Valve
Valve Spring
Ball Bearing
Crank Case
Crank Shaft
Piston
Connecting Rod
Cylinder
Anchorage Bolts
Rear Flywheel
Front Flywheel

Fig. 58.—Sectional Views Showing Construction of Autocar to Cylinder Crankshaft.

row ball bearings. Two flywheels are provided, one on either end of the shaft, so as to equalize the strain on that member and reduce engine vibration so that it is hardly appreciable. The camshaft is carried above the crankshaft and operates the valves through the medium of short push rods.

The Packard Four-Cylinder Motor.—The Packard engine, which is shown at Fig. 59, is an example of L-head construction in which the cylinder heads are cast integrally with the cylinder block. The general characteristics are similar in all sizes. The 25.6 horsepower engine of 4 inches bore and 5½ inches stroke is used in the 1½-ton and two-ton models. The 32.4 horsepower engine, which is used in a three-ton and four-ton truck has the same stroke as that previously mentioned; the bore size is increased to 4½ inches. An increase to 5 inches bore gives an engine of 40 horsepower, which is used on the five-ton truck. All motors have the four cylinders cast in a block and have a bell housing so that the clutch or clutch and transmission may be attached to form a unit power plant. The normal speed of all engines is 1,000 r.p.m. Engine suspension is by three points. The crankshaft is a four main bearing type and is exceptionally strong in design. Cooling is by pump circulation, a centrifugal pump being used. Lubrication is by forced circulation, a gear pump drawing oil from the engine pump and forcing it to the main bearings from which it passes through passages in the journals and crankpins to the connecting rod. A special form of hydraulic speed governor which is operated by the water circulation system is used to control the engine speed. The fan is a ball-bearing type and is driven by a V-belt. The valve mechanism is completely enclosed and valve plungers and cams are lubricated from the engine interior.

The Dodge Engine.—Many light trucks and delivery wagons are produced which have a modified Dodge Brothers chassis. The power plant is a very simple type and is shown distinct from the change speed gearing at Fig. 60. The engine is of the four-cylinder type with the cylinders cast in a single block together with the upper part of the crankcase. A pressed steel under or oil pan forms the lower half of the crankcase. The engine is mounted in the main frame on a three-point suspension, two of the points being on either side of the bell housing surrounding the flywheel, and the third a ball and socket joint at the front end of the engine timing gear cover plate. The bell housing is

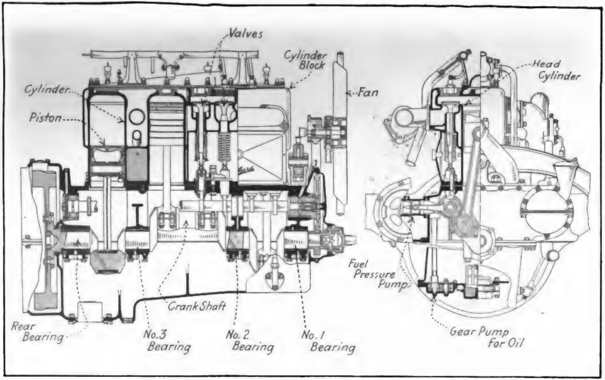

Valves
Cylinder Block
Fan
Head Cylinder
Cylinder
Piston
Fuel Pressure Pump
Crank Shaft
Rear Bearing
No.3 Bearing
No.2 Bearing
No.1 Bearing
Gear Pump for Oil

Fig. 59.—Sectional View Showing Construction of the Four-Cylinder Packard Motor Truck Engine.

cast as a unit with the transmission. Between the engine and bell housing the pressed steel rear motor support is bolted. The engine has a detachable cylinder head which carries the spark plugs and the priming cocks and serves as a cover over the intake and exhaust valves, which are in a side pocket of the L-head cylinder casting. Ignition is obtained with an Eisemann G-4 magneto in special army models and by battery and coil in the commercial models, equipped with electric starting and lighting systems.

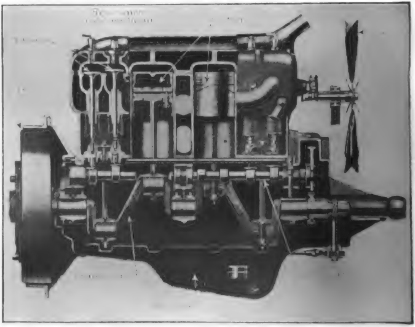


Fig. 60.—Part Sectional View Showing Construction of Typical Light Four-Cylinder Motor Truck Engine of the L Head Type with Detachable Cylinder Head.

Bore	inches	3.875 (3⅞)
Stroke	inches	4.500 (4½)
Piston Displacement	Cubic inches	212.5 (212½)
Horsepower, N. A. C. C. formula.......................	rating	24.03

The cylinder assembly is a block casting that includes not only the cylinder barrels but also the upper part of the crankcase. It therefore supports the crankshaft, the camshaft, and carries all of the valve gear. The cylinder head is detachable.

The underside of the crankcase is closed by the pressed steel oil pan, while the timing gears at the front end are enclosed by a cast iron timing gear cover plate, which also forms the front engine support.

The cylinders and the crankcase, which are cast integrally, are made from cast iron. The valves and the camshaft are located on the right hand side of the engine. The valve springs, valve lifters and guides are enclosed by valve cover plates to protect them from the dust and the dirt and thus prevent excessive wear. The cylinder block is bushed at three places to provide bearings for the camshaft. The valve guides are inserted in the cylinder casting and a pressed steel cup is provided at the juncture of the guide with the cylinder water jacket to give the valve spring a square and smooth seating. The valve lifter guides are inserted in holes provided above the camshaft in the cylinder casting. The exhaust manifold is attached to the right-hand side of the cylinder casting, but the intake manifold is cored in the cylinder casting and the carburetor is attached to the left-hand side of the engine block. The passage across the cylinder block from the carburetor to the intake distribution passage under the valves passes between the second and third cylinders of the block. The water inlet pipe is at-

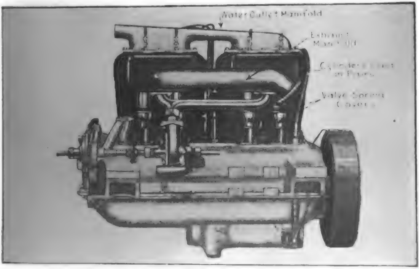
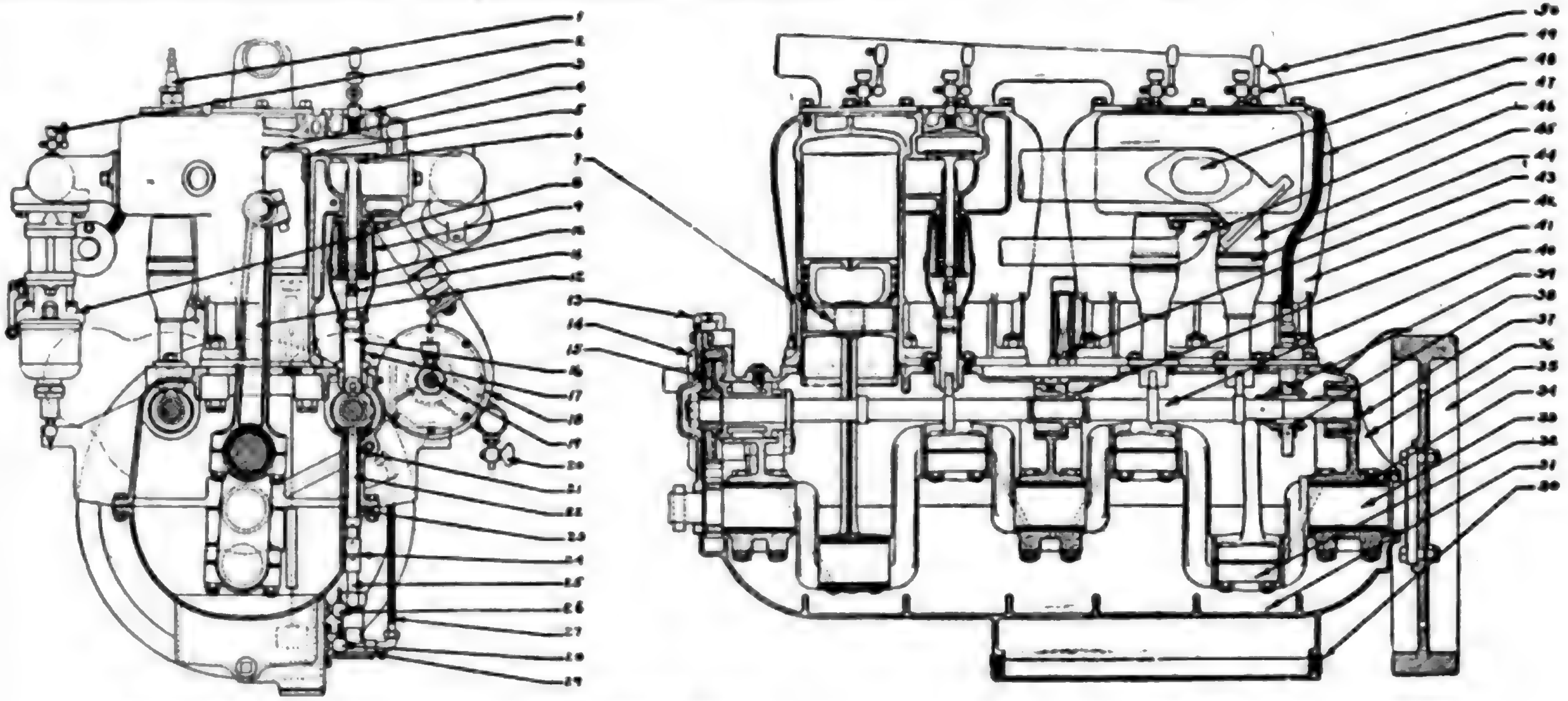


Fig. 61.—Side View of Wisconsin Four-Cylinder Motor Truck Engine.



1. Spark Plug.
2. Priming Cup for Intake Pipe.
3. Valve Cover.
4. Piston.
5. Piston Ring.
6. Exhaust Valve.
7. Wrist Pin.
8. Carburetor.
9. Valve Casing.
10. Valve Spring.
11. Valve Tapper Adjusting Nut.
12. Connecting Rod.
13. Main Oil Pipe.
14. Crank Case Front Cover.
15. Cam Shaft Gear.
16. Valve Tapper.
17. Valve Tapper Guide.
18. Water Pump.
19. Water Pump Drive Shaft
20. Drain Cock.
21. Upper Oil Pump Shaft Bushing.
22. Upper Oil Pump Shaft.
23. Lower Oil Pump Shaft Bushing.
24. Oldham Coupling for Oil Pump Shaft.
25. Lower Oil Pump Shaft.
26. Upper Crank Case Drain Cock.
27. Flexible Oil Line.
28. Lower Crank Case Drain Cock.
29. Oil Pump.
30. Crank Case Drain Plug.
31. Crank Case, Lower.
32. Connecting Rod Bearing Cap.
33. Crank Shaft.
34. Rear Main Bearing.
35. Fly Wheel.
36. Crank Case, Upper.
37. Rear Cam Shaft Bearing.
38. Upper Oil Pump Shaft.
39. Governor Shaft.
40. Exhaust Cam Shaft.
41. Center Cam Shaft Bearing.
42. Rear Cylinder.
43. Oil Gauge.
44. Valve Casing Clip.
45. Valve Casing.
46. Inlet Water Manifold.
47. Governor Flexible Tube.
48. Exhaust Manifold.
49. Priming Cup.
50. Upper Water Manifold.

Fig. 62.—Part Sectional Views Showing Interior Construction of Four-Cylinder Wisconsin Motor Truck Engine.

tached to the right lower front corner of the cylinder water jacket with a single cap screw. The water is delivered to this point by the centrifugal water pump provided. On the front end of the cylinder water jacket there is a boss, to which is attached the cooling fan support bracket. The crankshaft main bearings are in the upper part of the crankcase, which, as mentioned, is cast integral with the cylinder block. There are three bearings, the caps of which are all held in place by studs which are screwed into the cylinder casting. Two studs are provided for each of the main bearing caps.

Wisconsin Engines.—A well-known and very practical line of engines for motor truck use is produced by the Wisconsin Motor Manufacturing Company of Milwaukee, Wis. The model shown at Figs. 61 and 62 is used on the F. W. D. truck and others, and has been very successful in this application. The engine is located longitudinally of the truck, under the driver's seat, on a sub-frame which also supports the transmission. It is a four-cylinder, four-stroke cycle; T-head of 4.75 inches bore and 5.5 inches a stroke. The piston displacement is 389.84 cubic inches. The cylinders are cast in pairs. The engine is supported on the sub-frame by four supporting arms cast integral with the aluminum crankcase upper half, two bolts passing through each arm maintaining the alignment. The engine is of the conventional type with a timing gear case located at the front. The two camshafts are driven by the crankshaft timing gear through an idler gear running on a stud fastened in the crankcase. The magneto and pump shaft gears are driven by the camshaft gears.

The oil pump, located in the bottom of the crankcase pump on left side of engine, is driven through bevel gears and a vertical shaft from the exhaust camshaft. The engine is equipped with a governor, operating on a throttle between the carburetor and manifold, and driven from the exhaust camshaft through bevel gears and a flexible shaft.

The fan, which is located just behind the radiator, is driven by a leather belt from the fan pulley located at the front end of the fan shaft, having a flexible coupling at each end, and driven from the extension of the water pump driving shaft which projects through the crankcase front cover. Ignition is supplied by an Eisemann high-tension variable spark magneto located on right side of engine in front of the carburetor. The carburetor is a Stromberg Model G, size 3 (1.5-inch), double jet fixed nozzle air valve type. Gasoline is supplied by gravity through copper tubing from the gasoline tank, located behind the seat.

The engine, depicted at Fig. 64, is one of the Liberty models of Wisconsin design. The type R.A.U. has cylinders 4.75 x 6-inch bore and stroke; the R. B. U. has a bore of 5-inch and a stroke of 6-inch. These two have their cylinders cast in pairs, with detachable cylinder heads. The L-head cylinders are bolted to the aluminum crankcase. These engines are specially designed to handle the lower grades of fuel which are now offered on the market. The crankshafts are made of chrome nickel

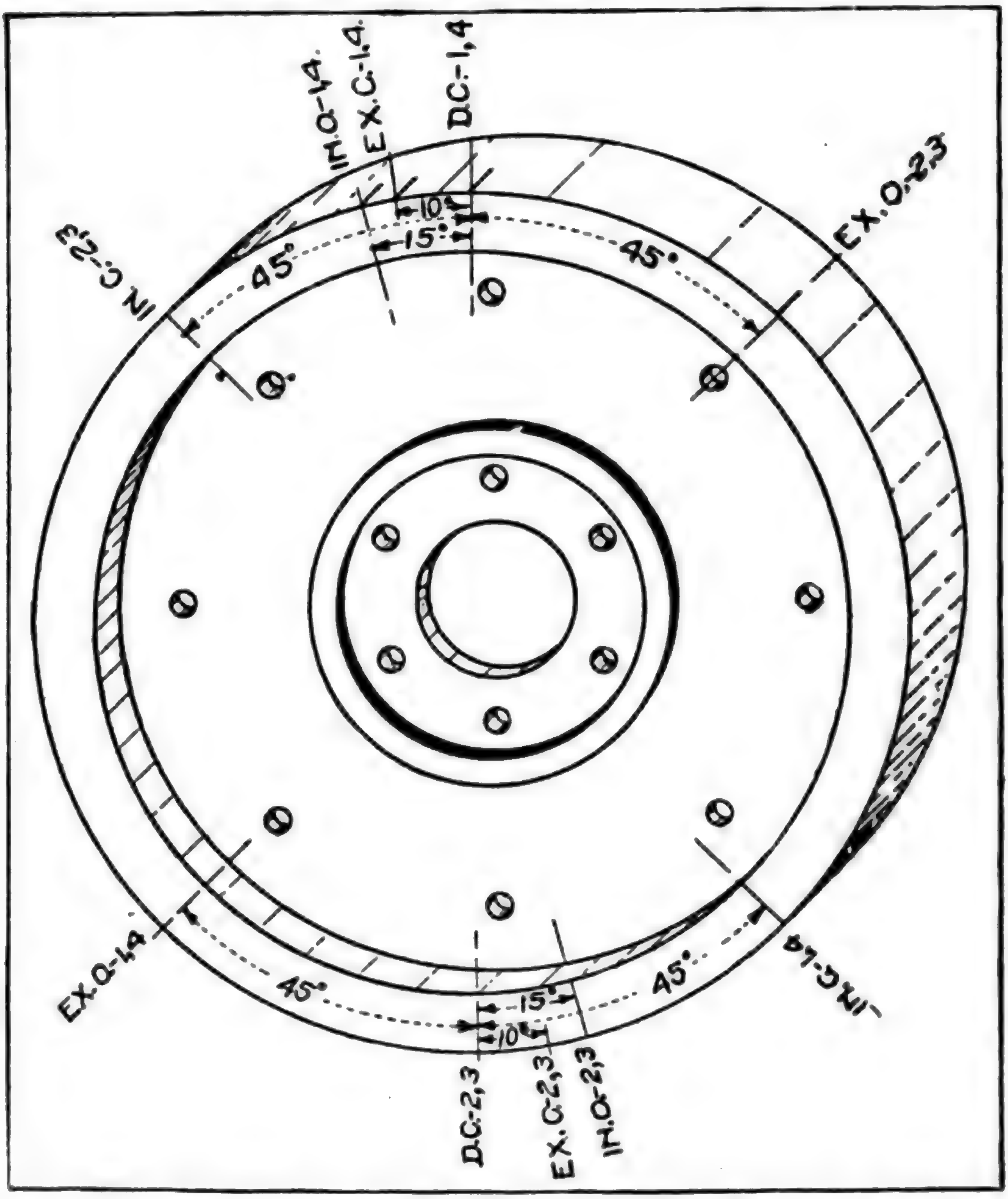

IN.O.-1,4.
EX.C.-1,4.
D.C.-1,4
10°
15°
45°
45°
IN.C.-2,3
EX.O.-2,3
EX.O.-1,4
IN.C.-1,4
45°
45°
15°
10°
D.C.-2,3
EX.C.-2,3
IN.O.-2,3

Fig. 63.—Diagram Showing Valve Timing of Wisconsin Motor Truck Engine.

steel, 2¼ inches in diameter on the crankpin and 2¼, $2\frac{5}{16}$ and 2⅜ inches diameter on the front, center and rear main bearings respectively.

The crankcase is made of aluminum, with massive webs supporting the bearings. At the forward end there is a large, combined breather and oil filler, and an indicating oil gage is located on the same side of the case at the rear. As indicated by the "U" in the type designation of the engine, these two models are of the unit power plant type, and the flywheel is enclosed in a bell housing which is cast integral with the crankcase. The three-point system of suspension is used, and special emphasis is laid on the fact that the engine has an "all steel" suspension. At the front it is supported on a trunnion bearing formed on the timing gear housing cover, while at the rear there is a cast steel or malleable supporting beam which is bolted to the bell housing.

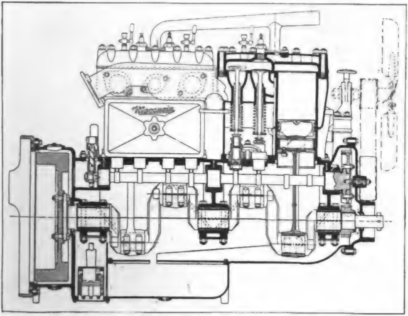


Fig. 64.—Part Sectional View of Late Model Wisconsin Truck Engine Having Detachable Cylinder Heads and Cylinders Cast in Pairs.

The Buda Engine.—The model of this well-known make that is used on the Nash truck is shown at Fig. 65, and is rated at 27.5 horsepower. The cylinders, which are cast in a block, with integral cylinder heads, are 4½-inch bore and 5½-inch stroke. The power plant is designed for independent mounting and is

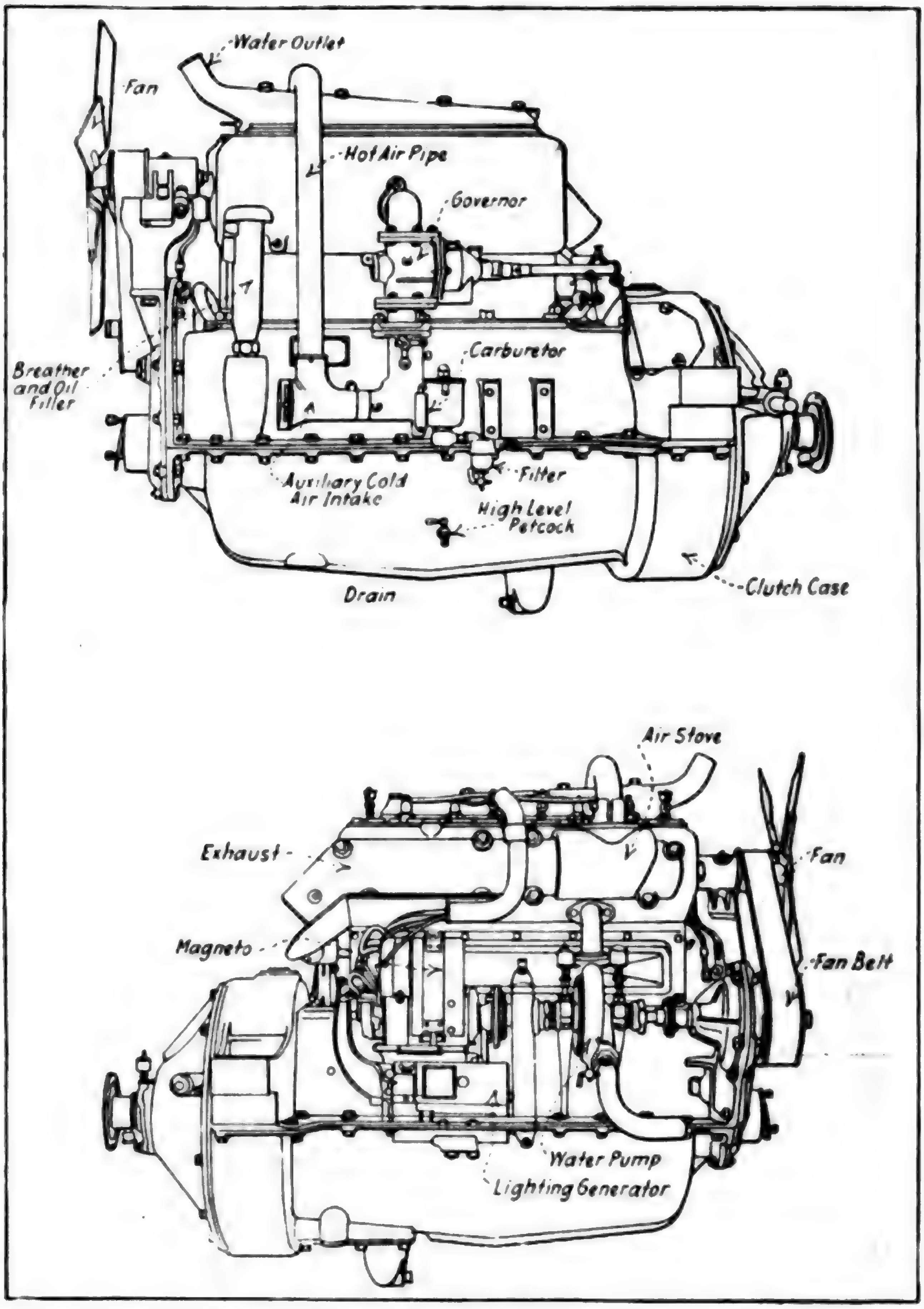

Water Outlet
Fan
Hot Air Pipe
Governor
Carburetor
Breather and Oil Filler
Auxiliary Cold Air Intake
Filter
High Level Petcock
Drain
Clutch Case
Air Stove
Exhaust
Fan
Magneto
Fan Belt
Water Pump
Lighting Generator

Fig. 65.—Exterior Views of the Nash-Buda Four-Cylinder Motor Truck Engine Showing Location of Important Auxiliary Parts.

intended to be supported by a three-point suspension in which there is one supporting point at the front and two arms at the rear which are cast integrally with the flywheel and clutch housing. The engine develops its rated horsepower at 1,200 r.p.m., which is the normal speed. The crankshaft is a three main bearing type, the front bearing being 2⅛ x 3¼ inches, the intermediate or center bearing being 2⅜ x 4 inches and the rear 2¼ x 2¾ inches. The connecting rod crankpin bearings are 2⅛ x 2½ inches; the wristpin is 1⅛ in diameter. The piston is provided with three ¼-inch piston rings. A centrifugal pump is used for water circulation and a 19-inch diameter belt-driven fan induces a positive air draft through the radiator. Ignition is by high tension magneto and speed control is by centrifugal governor.

The Buda engine shown at Fig. 66 in part section is the model H.T.U., which is rated at 35 horsepower and has cylinders 4¼-inch bore by 5½-inch stroke. The four cylinders are cast in a block, but the cylinder head is removable so that the valves and pistons may be easily reached by its removal. The engine is provided with a standard bell housing and may be moved independent of the change speed gearing or combined with that member to form a unit power plant with three point suspension. It is stated that it delivers its rated horsepower at 1,100 r.p.m. The valve opening is 1⅞ inches, which allows a free ingress and egress of the gases. It will be seen that the crankshaft is the conventional three bearing type, and is drilled with passageways through the crank webs to insure correct distribution of the lubricating oil. The front main bearing is 2⅛ x 3⅛ inches, the center main bearing is 2¼ x 3¼ inches, and the rear main bearing is 2⅜ x 4 inches. The connecting rod big end bearing is 2¼ inches bore and 2½ inches wide. The wristpin is 1⅛ inches in diameter by 2⅛ inches width bearing. A circulating oil system is used. Water circulation is by centrifugal pump. The cooling fan is 18 inches in diameter, but is not shown in the illustration. The exhaust pipe bore is 2½ inches, and a 1¼-inch bore inlet pipe supplies the gas to the valve chamber. Spark plugs are standard S.A.E., ⅞-inch diameter, 18 thread. A centrifugal governor is utilized to keep the engine speed from exceeding a safe maximum.

Hercules Four-Cylinder Truck Motor.—An unusual type of four-cylinder engine is shown at Fig. 67. This is the Hercules M. which is intended for a truck of three-ton capacity. It is rated at 28.9 horsepower and has four cylinders cast in a block which are 4¼ inches bore and 5½ inches stroke. A distinctive feature is the provision of individual removable cylinder head,

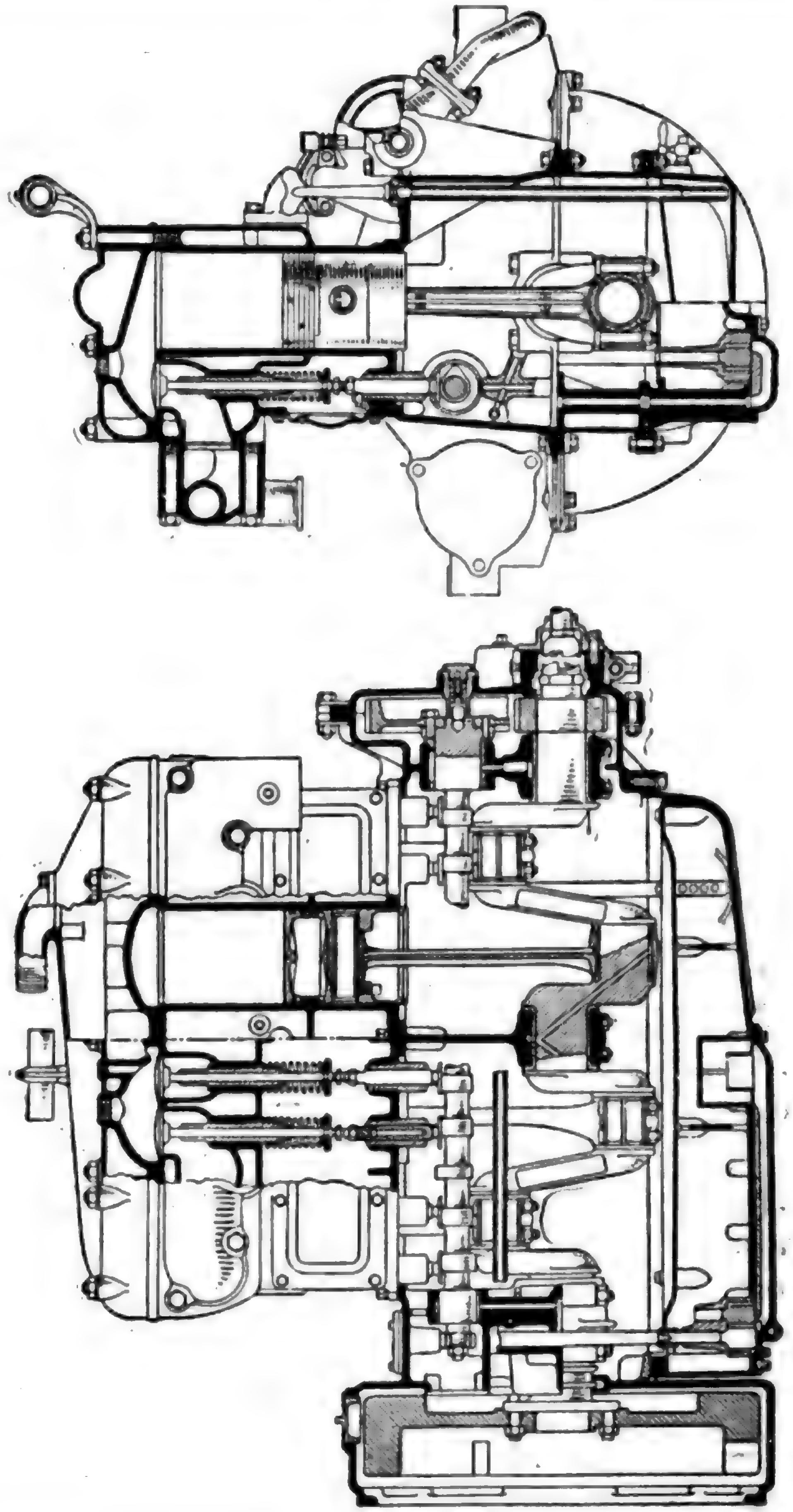


Fig. 66.—Sectional View Showing Construction of Buda Model H. T. U. Truck Engine.

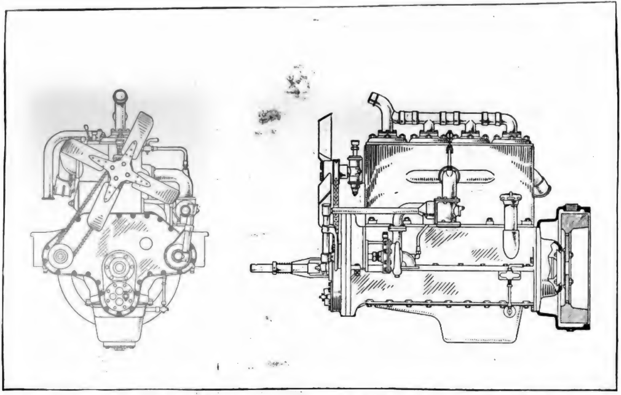


Fig. 67.—The Hercules Series M Four-Cylinder Truck Engine is a Distinctive Type Employing Four Cylinders Cast in a Block but Having Individually Cast Separable Cylinder Heads.

one being provided for each cylinder, but not including the valve chambers which are closed by the usual form of screw plugs. The engine develops its power at a normal speed of 1,100 r.p.m. The valves are large for a cylinder of the diameter given, as they are 1⁹⁄₁₆ inches in diameter. The crankshaft is a five bearing type, all crank journals being two inches in diameter. The front main bearing is 3 inches long, the rear main bearing 4⅜ inches long, while the three intermediate bearings are each 2 inches in length. The connecting rod big end is 2 inches bore and 2½ inches long. Ample bearing is also provided at the wristpin, which is 1¼ inches in diameter, which has a bearing 1¹³⁄₁₆ inches long. The pistons are provided with five ³⁄₁₆-inch width rings. Lubrication is by circulating system and a pump of the centrifugal type keeps the water moving. An 18-inch diameter, four-blade fan is driven by a built-up V section leather belt. The exhaust pipe is 2½ inches bore and a standard S.A.E. flange intake 1¼ inches bore is furnished. The weight of the engine is given as 700 pounds.

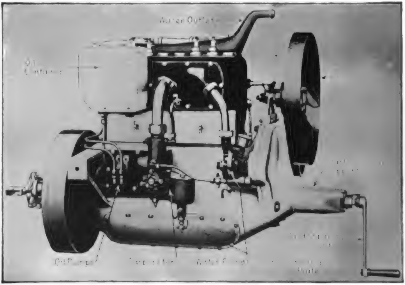


Fig. 68.—Four-Cylinder Motor Used in Three-Quarter-Ton and Two-Ton Capacity White Trucks.

White Truck Engines.—The White motor trucks are used in very large quantities and are equipped with two different forms of power plant. That shown at Fig. 68 is used on the trucks

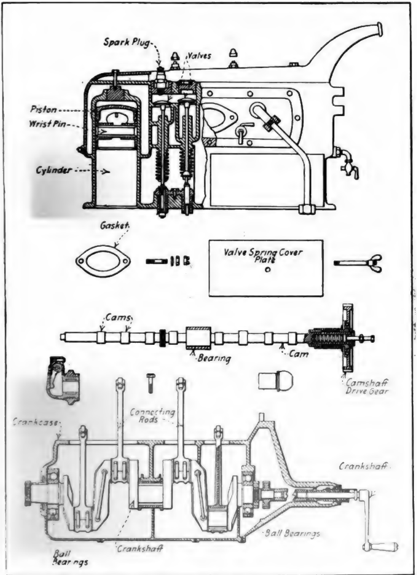

Spark Plug
Valves
Piston
Wrist Pin
Cylinder
Gasket
Valve Spring Cover Plate
Cams
Bearing
Cam
Camshaft Drive Gear
Connecting Rods
Crankcase
Crankshaft
Ball Bearings
Crankshaft
Ball Bearings

Fig. 69.—**Parts of White Truck Engine Showing Cylinder Block Construction, Camshaft and Ball-Bearing Crankshaft.**

ranging in capacity from three-quarters of a ton to two tons and is rated at 22.5 horsepower. It is remarkably simple and compact in construction. As will be seen by reference to Fig. 69, the four cylinders are cast in a block and are 3¾ inches bore and 5⅛ inches stroke. The engine is designed for independent mounting and delivers its rated horsepower at a normal speed of 1,400 r.p.m. The distinctive feature of this model engine is the use of ball bearings for crankshaft support at front and rear, while the center bearing is a plain white metal bushed type. The White G.N. motor, which is shown at Figs. 70 and 71, is used on the three- and five-ton trucks, and is rated at 28.9 horsepower. The cylinders, which are cast in a block, have a detachable cylinder head. The bore is 4¼ inches, the stroke 5¾ inches. The power plant is designed so that it may be run at 1,600 r.p.m. without any danger of premature depreciation. It is combined with a clutch and change speed gearing to form a unit power plant with three point suspension.

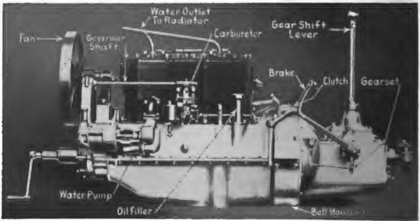


Fig. 70.—The White G. N. Unit Power Plant Used in the Three-and-One-Half and Five-Ton Trucks.

International Harvester Truck Engines.—The engine used in the one-ton International Harvester Company truck is known as the Model E, and its construction is clearly shown at Fig. 72. The external view at A shows a departure from the usual construction, because the fan is mounted at the rear of the cylinder block instead of at the front end. This is made necessary because the radiator on this truck is carried back of the engine instead of at the front end. It will be also noted that the water outlet pipe, at the top of the cylinder, discharges to the rear instead of to the front. The engine is of the four-cylinder type, having the cylinder cast in a block with integral cylinder head and water jackets of liberal proportions. It is 3½ inches bore and 5¼ inches stroke. The magneto and water circulating pump

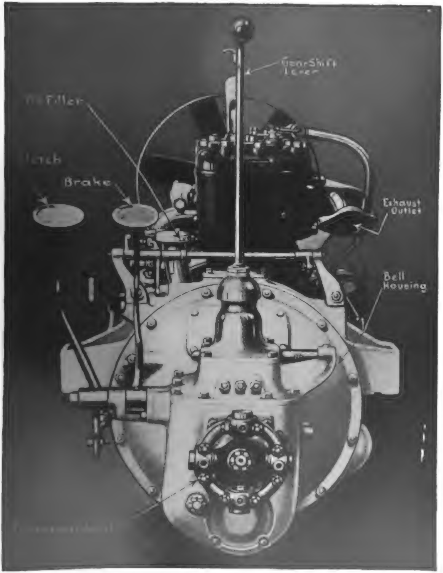

Gear Shift Lever
Oil Filler
Clutch
Brake
Exhaust Outlet
Bell Housing

Fig. 71.—**Rear End View of the White Model G. N. Unit Power Plant.**

are located at the front end of the engine and are driven by spiral gearing. A special design centrifugal governor is mounted at the front end of the crankshaft and works the carburetor throttle valve through enclosed leverage, so it cannot be tampered with. The sectional view of the engine at Fig. 72, B, outlines the salient points of construction very clearly.

The engine used on the Model G International Harvester Trucks, which are of two-ton capacity, is clearly shown at Fig. 73. The exterior view at A depicts the location of power plant auxiliaries and the clean-cut appearance of the engine.

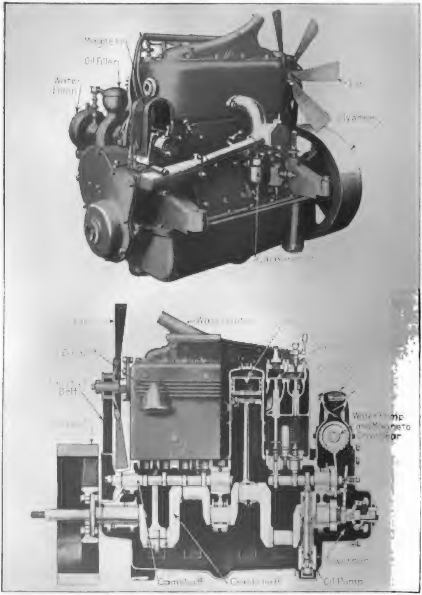

Magneto
Oil Filler
Water Pump
Belt
Water Pump and Magneto Drive Gear
Camshaft
Crankshaft
Oil Pump

Fig. 72.—View at A Shows External View of the Model E Engine Used in the One-Ton Capacity I. H. C. Truck. Sectional View Showing Interior Construction of This Engine at B.

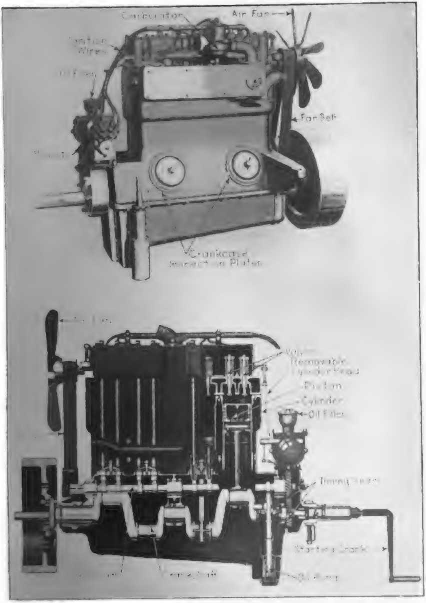

Carburetor
Air Fan
Ignition Wires
Oil Filler
Fan Belt
Crankcase Inspection Plates
Valves
Removable Cylinder Head
Piston
Cylinder
Oil Filler
Timing Gears
Starting Crank
Oil Pump

Fig. 73.—External View of the Model G I. H. C. Engine, Used on Two-Ton Trucks. Sectional View at B Shows Interior Arrangement and Application of Overhead Valve Principle.

The sectional view at B shows the important internal parts clearly. The appearance of the different parts comprising the engine assembly when it is dismantled are very clearly outlined

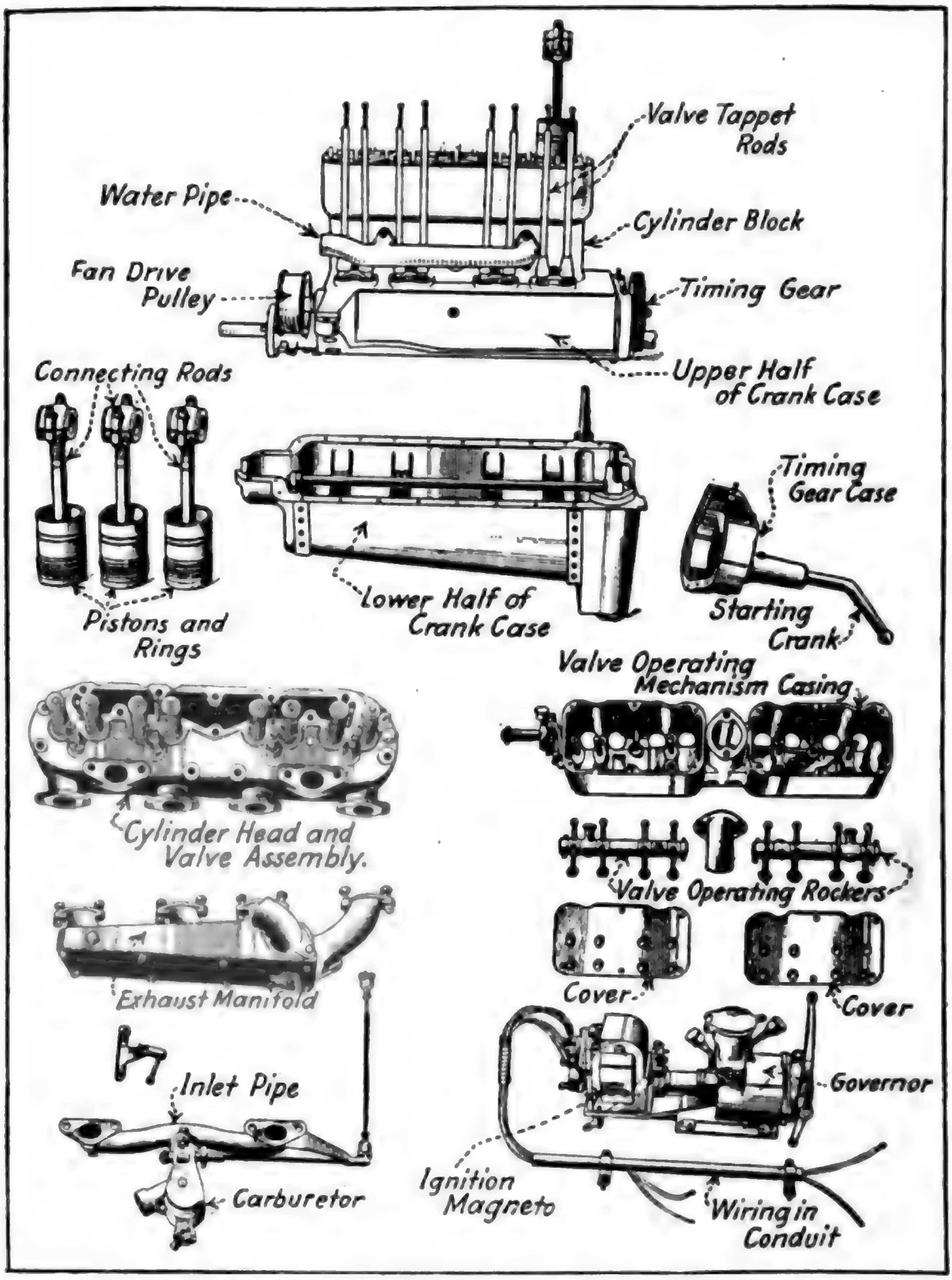

Valve Tappet Rods
Water Pipe
Cylinder Block
Fan Drive Pulley
Timing Gear
Upper Half of Crank Case
Connecting Rods
Timing Gear Case
Pistons and Rings
Lower Half of Crank Case
Starting Crank
Valve Operating Mechanism Casing
Cylinder Head and Valve Assembly.
Valve Operating Rockers
Exhaust Manifold
Cover
Cover
Inlet Pipe
Governor
Ignition Magneto
Carburetor
Wiring in Conduit

Fig. 74.—Showing Important Parts of the Model G, I. H. C. Motor Truck Engine, When Dismantled.

at Fig. 74. This engine has the cylinders cast in a block with a detachable cylinder head carrying the overhead valves. The cylinders are four-inch bore and five-inch stroke. The valves are so mounted as to open directly into the cylinder and are actuated by overhead rocker levers, which are in turn operated from the camshaft carried in the engine base by vertical tappet rods. As is true of the Model E engine, the magneto and water pump is driven by a cross shaft at the front end of the motor and the fan is placed at the rear end. The valve mechanism is completely enclosed by a cast housing so that there is no opportunity for dirt or grit to get into the bearings of the valve mechanism.

The Riker Truck Motor.—The illustrations at Figs. 75 and 76 show the Riker motor which is used on the three- and four-ton jobs, built by the Locomobile Company. It is rated at 28.9 horsepower. The cylinders are 4¼-inch bore by 6-inch stroke, and are cast in pairs. They are of the T-head form, in which the valves are carried on opposite sides of the cylinder. The engine is designed for independent mounting and has a normal speed of 1,180 r.p.m. The crankcase is supported by three points. The valve openings are 1¾ inches in diameter, the crankshaft is of the five main bearing type, the front bearing is 2¼ inches in diameter by 4¼ inches long, the rear 2¼ x $4\frac{11}{16}$

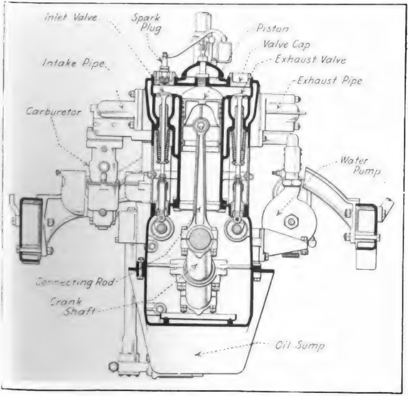

Inlet Valve
Spark Plug
Piston
Valve Cap
Exhaust Valve
Intake Pipe
Exhaust Pipe
Carburetor
Water Pump
Connecting Rod
Crank Shaft
Oil Sump

Fig. 75.—Sectional View of Riker Motor Truck Engine.

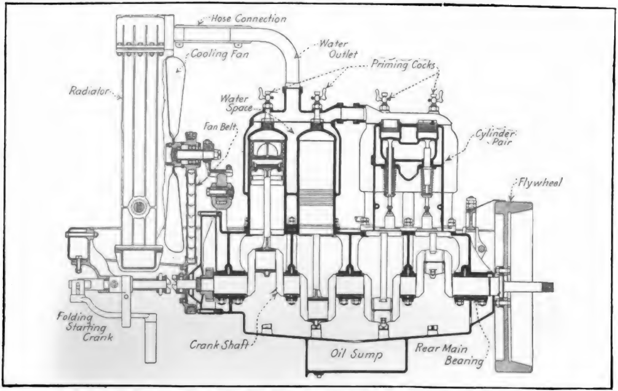

Hose Connection
Water Outlet
Cooling Fan
Priming Cocks
Radiator
Water Space
Fan Belt
Cylinder Pair
Flywheel
Folding Starting Crank
Crank Shaft
Oil Sump
Rear Main Bearing

Fig. 76.—Longitudinal Sectional View of the Riker Motor Truck Power Plant.

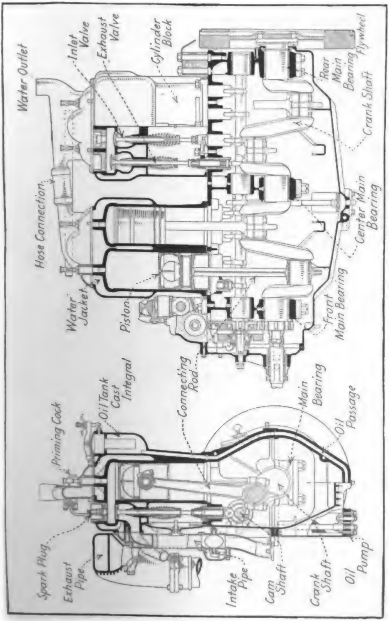

Spark Plug
Exhaust Pipe
Intake Pipe
Cam Shaft
Crank Shaft
Oil Pump
Priming Cock
Oil Tank Cast Integral
Connecting Rod
Main Bearing
Oil Passage
Water Jacket
Piston
Hose Connection
Front Main Bearing
Center Main Bearing
Water Outlet
Inlet Valve
Exhaust Valve
Cylinder Block
Crank Shaft
Rear Main Bearing
Flywheel

Fig. 77.—Sectional View Showing Construction of the Four-Cylinder Engine Used on Mack A. C. Trucks.

inches, intermediate bearings $2\frac{1}{4} \times 3\frac{1}{2}$ inches. The connecting rod big end is $2\frac{1}{4}$ inches bore and $2\frac{1}{2}$ inches width. The wrist pin bearing is $1\frac{5}{16} \times 2\frac{1}{4}$ inches. The pistons are long, so as to obtain a full bearing in the cylinder walls, and are provided with five $\frac{1}{8}$-inch width packing rings, four being carried above the wristpin and one below that member. The lubrication is by a circulating oil system. A centrifugal water pump insures circulation and a 24-inch diameter belt-driven ball bearing fan promotes a positive air flow through the radiator. The exhaust is $2\frac{3}{8}$ inches, the intake $1\frac{1}{2}$ inches bore. The engine is a governed type and its weight is given as 1,000 pounds.

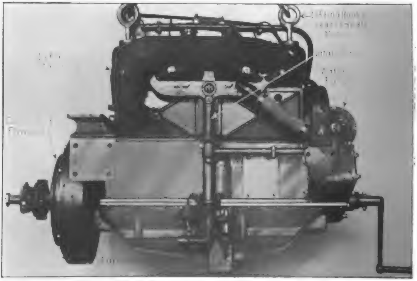


Fig. 78.—External View of the Four-Cylinder Engine Used on Mack A. C. Trucks.

Mack Truck Motors.—The part sectional view at Fig. 77 depicts a very successful heavy duty engine of the four-cylinder type which is used on the Mack A. C. trucks of $3\frac{1}{2}$- to 5-ton capacity. The cylinder bore is five inches and the stroke six inches. The cylinders are cast in pairs and are of the L-head form. The exterior view of the engine at Fig. 78, as it looks from the valve side, shows a substantial construction and the system of supporting the crankcase. The engine is designed for three point support and is attached to the frame at four points. The manner in which this is accomplished is shown

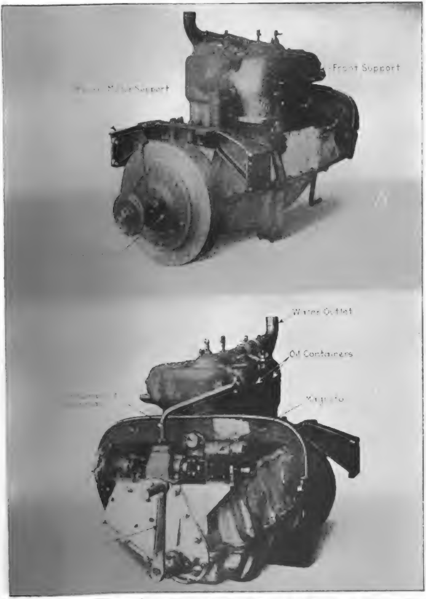

Front Support
Water Outlet
Oil Containers
Magneto

Fig. 79.—Rear View of the Mack A. C. Truck Engine at A Shows Rear Engine Hanger. Front View of This Power Plant at B Shows the One-Point Support of the Front End of the Crankcase, Also Location of Pump and Ignition Magneto.

at Fig. 79. The rear view at A shows a substantial steel casting rigidly bolted to the engine crankcase providing two points of support, each side of this casting resting on the frame member and being fastened thereto by four substantial bolts. The view at B shows how this engine is supported by a trunnion bearing at the center of the front supporting arm, which is also a substantial steel casting. Even though the arm is attached to the truck frame at each side, the engine support by the rocking trunnion bearing at the center of this casting gives the three point suspension that is so desirable. As this engine is installed ahead of the radiator, which is placed just forward of the dash, the water outlet pipe points to the rear. The magneto and water pump are located at the front end and are driven by a cross shaft. A novel system of lubrication is used with this engine, in which the oil reservoir is cast integrally with the cylinder block so that the oil is maintained in a heated condition in the Winter and assists in cooling the engine during the Summer. This oiling system will be described in proper sequence.

Power Plant Installation.—The method of installing the power plant varies on different types of automobiles, though the majority of cars have the engine placed at the extreme front end of the chassis. In some early types of cars, where double-cylinder motors of the horizontal type were used, the motor was placed under the body. This type of construction is nearly obsolete at this time and is found only on one commercial car, and in this the motor is located under the seat.

The power plant is often combined with the clutch and change speed gearing in such a way as to form a unit construction. This method of joining the parts is widely used at the present time, and is superior to the other common method, where the motor and change speed gears are independent units. Each method has advantages. As will be evident when the gearset and motor are separate, the transmission may be removed from the chassis frame without disturbing the power plant, and vice versa. At the other hand, when the unit construction, as shown at Fig. 70, is used, it is sometimes difficult to remove one member without having to take the entire unit from the frame. In some trucks, notably the chain drive models, it is preferable to have the change speed gearing combined with the countershaft rather than with the power plant.

The unit construction has the advantage of retaining positive alignment of the gearset with the engine indefinitely. This relation between the parts is obtained when they are first assembled

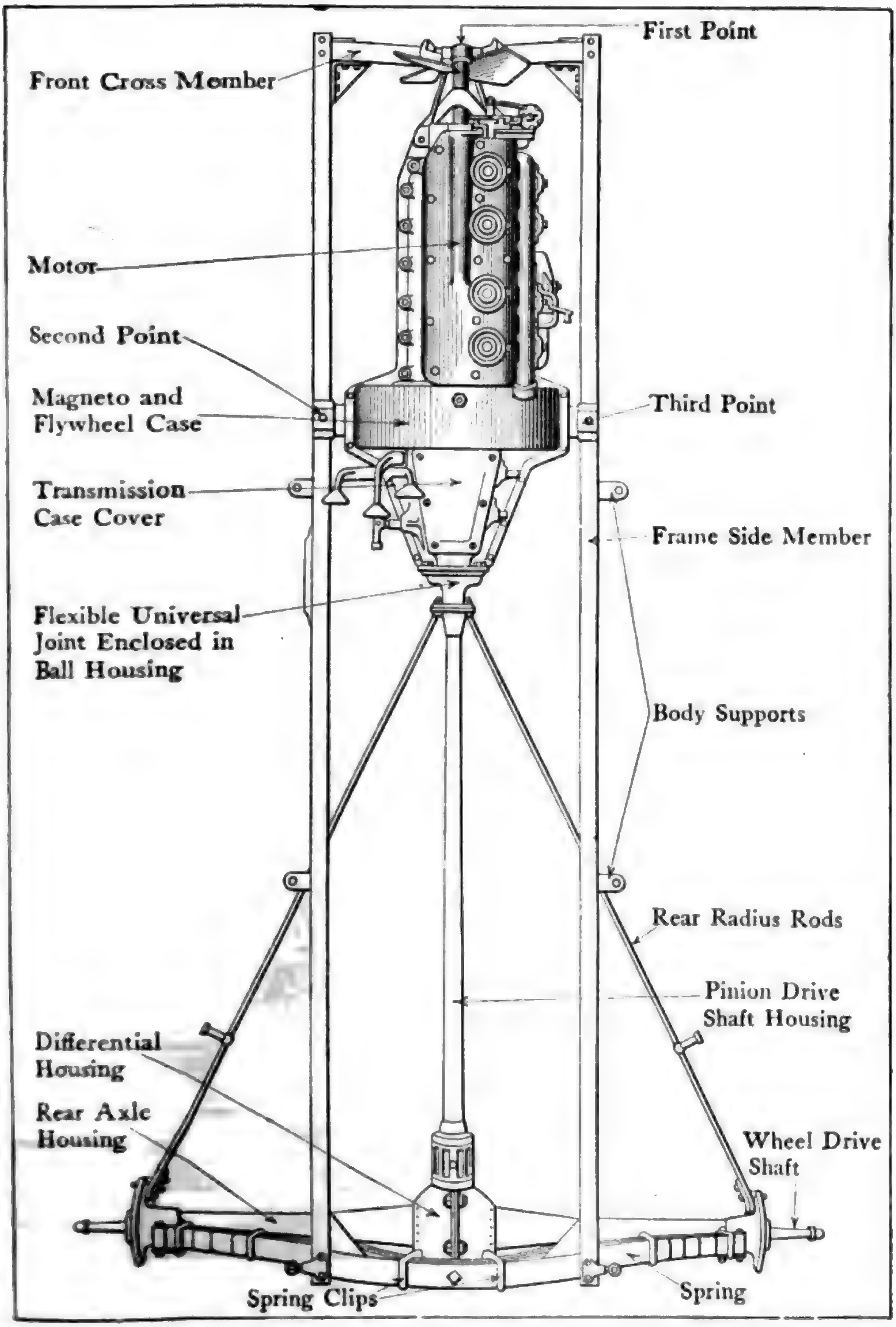

First Point
Front Cross Member
Motor
Second Point
Magneto and Flywheel Case
Third Point
Transmission Case Cover
Frame Side Member
Flexible Universal Joint Enclosed in Ball Housing
Body Supports
Rear Radius Rods
Pinion Drive Shaft Housing
Differential Housing
Rear Axle Housing
Wheel Drive Shaft
Spring Clips
Spring

Fig. 80.—Plan View of the Ford Model T Frame with Power Plant and Rear Axle in Place Showing Three-Point Suspension Principle Utilized in This Design.

and the alignment cannot be changed by any condition of operation after the unit is installed in the frame. This method of mounting also permits the three-point suspension which is very desirable. For instance, the power plant shown at Fig. 61 is to be supported on four points, and the gearset is supported on another series of four points. While the tendency of these members is to brace the frame and prevent disalignment, it is possible on extremely rough roads for the frame distortion to vary the relation of the transmission and engine shaft to some extent. Where a three-point suspension is employed, as outlined at Fig. 80, the frame distortion will not impose stress on the power plant, because in a rigid unit construction all parts must remain in alignment. The advantages of this design are becoming better appreciated, and it is widely used at the present time.

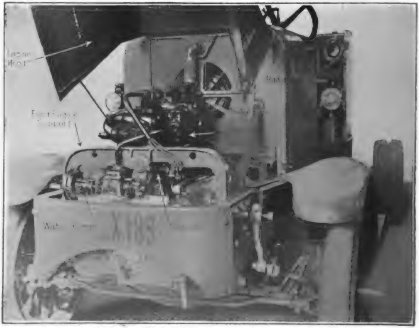
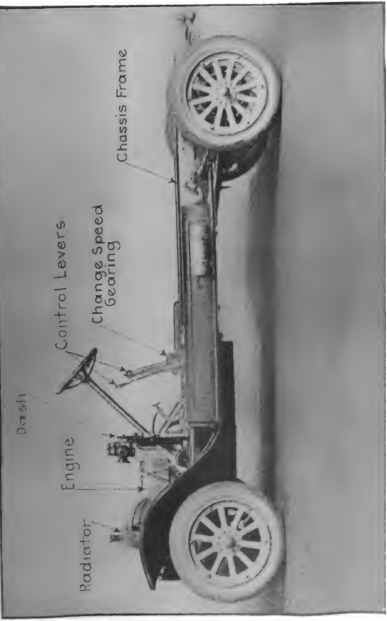


Fig. 81.—Front View of Mack A. C. Truck Showing Method of Power Plant Installation and Location of Engine Ahead of the Radiator.

At Fig. 55, a typical four-cylinder power plant and transmission unit adapted for three-point support is clearly shown. To show the method of power plant installation that is generally employed when engine and gearset were separate units, the view

Power Plant Installation


Radiator
Engine
Dash
Control Levers
Change Speed Gearing
Chassis Frame

at Fig. 81 is presented, this showing a typical four-cylinder power plant viewed from the front, showing clearly the method of supporting the engine base by four arms and yet obtaining a three-point suspension of the engine. In most types of commercial vehicles the motor is installed at the front end, under the hood, as in pleasure car practice, as outlined at Fig. 82, but in rare cases it is placed at practically the same point, but under floor boards or driver's seat.

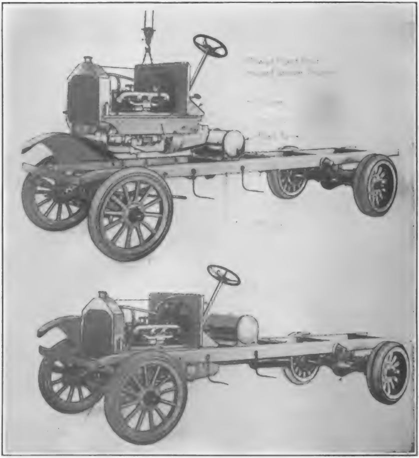


Fig. 83.—Diagram Showing Construction of Removable Power Plant Unit in Maccar Truck.

The advantages of the motor under the seat location may be very well summed up by saying that it permits more loading space and less over-all or wheel base for a given carrying capacity. The shorter wheel base vehicle is especially valuable in congested city traffic, because it may be more easily controlled when driving in narrow thoroughfares, taking corners, or backing up to a loading platform. The main advantage advanced for the motor in front type of commercial vehicle is accessibility of power plant, which may be easily reached by raising the hood. This feature is not lost when the motor is placed under the seat, however, because all average adjustments may be made by raising the floor boards or by opening a hinged door at the side of the motor compartment.

Some makers install the motor in a sub-frame and arrange the components in such a manner that they may be removed as a unit, permitting ready access to the motor and making for its prompt removal in event of overhauling or serious accident. Such a construction is shown at Fig. 83, which depicts a medium capacity truck with the power plant units removed from the frame. It will be seen that this unit includes the radiator, control levers, engine, gearbox and frame for the support of the floor boards. The seat unit is separate and is designed to fit over the fuel tank when it is in place on the chassis. This construction has advantages, but is unusual at the present time, only one maker producing trucks having this feature.

Engine Design for Pneumatic Tired Trucks.—In a letter published in "Automobile Industries," H. L. Horning, General Manager of the Waukesha Motor Company, a well-known builder of motor truck and tractor motors, discussed engine design for pneumatic tired trucks that are now the vogue for many purposes. The information given is based on a wide experience and cannot fail to be of interest to any reader interested in truck engine design.

Fuels are not going to improve in volatility, but rather will decrease, reaching an end point of 500 degrees Fahr. in 1925. This, we estimate, will be higher than the average offered then, but will have to be handled well by the vaporizers if the motors are not to be injured. Therefore, for a given size engine, there must be an allowance made for the loss in weight of charge due heating mixture and, hence, in power. Likewise, an allowance will be made for lower compression possible because of the detonation tendency of higher end point fuels. For a given engine displacement, the loss in power due to all these factors will be at least ten per cent at medium speeds. Therefore, to maintain power at a given speed, the displacement should be at least eleven per cent greater.

Pneumatic tires for trucks are only a matter of development. They must come, for they solve so many mechanical and transportation problems. Pneumatic tires mean speed of truck, and in order to keep high the ratio of net to gross weight and economy of engine performance by maintaining a high load factor, the engine must be of higher displacement, but also must be capable of higher sustained engine speeds. For a given sized truck, it is advisable to use at least twenty per cent higher displacement for pneumatic tires. We, therefore, have an engine of thirty-three per cent greater displacement for a given capacity of pneumatic tired job with poorer fuel than with solid and good fuel.

We must have greater speed of engine for the purpose of added power to sustain the higher truck speeds on the higher gears. Higher motor speeds will lessen the detonation tendency of lower grade fuels. Higher engine speeds mean lighter engine weights per power developed, a factor that reduces tractive resistance as well as gross weights.

Higher engine speeds demand stiffer crankcase and crankshafts and larger bearings. This is particularly true of the center crankshaft bearing and rod bearings. Class B practice of center and rear bearings alike, with front main and rod bearings alike, admirably meets the problem of increasing speed, as well as attaining a service ideal. High engine speeds make it imperative to have connecting-rod bearings on the piston center. Offset rod bearings have no place on modern engines. This is particularly necessary for smooth running when the engine is old. High engine speeds under load are not detrimental to well-constructed engines, but high speeds with no load are very damaging. We, therefore, plan for a maximum speed governor to hold the idle speed within reason. Smaller engines can run at higher speeds, due to better cooling, hence the crankshafts should be relatively larger. We have, therefore, made all engines from 289-inch to 492-inch displacement of the same diameter of crank, with all camshaft holes the same as crank, so that service reamers can be used on main rods and camshaft bearings. High speed in engines demand ample valve capacity, which need not mean larger valve sizes or excessive lifts. For economy, gas velocities should be such as will assure good turbulence of charge, giving higher velocities.

For highest economy of operation the engine should be so designed as to give a flat economy curve, and special effort should be made to give a good economy for half loads and less. The application should be so worked out that the average speed of truck corresponds to the speed of maximum economy, and when in this position the speed of maximum torque will be about ten per cent lower. Trucks seldom average over fifty per cent of the governed speed. High engine speeds demand a water pump of special characteristics. A centrifugal pump which will give ample water at speed is usually unfit for slow truck speeds at high temperatures. If satisfactory for slow speed and high temperatures, it keeps the water temperature too low for economy at high speeds. There are reasonable limits beyond which it is not practical to go, either in piston speeds or r.p.m. Therefore, some of the increase in truck speed must be provided for in gear ratios.

The difference between some stock engines of old types and new types may be expressed as follows: An old-type engine would not go one-tenth as long at 1,800 revolutions full load as a new-type engine. On high speed engines valve trouble will be greater and some effort at rotation will probably be necessary. Far better engineering and experimental work will have to be done on the trucks designed for pneumatic work than has been done on solid-tired job. The present practice of letting over-enthusiasm force acceptance of a new model will give way to a persistant effort to attain an ileal in performance.

CHAPTER III

MOTOR TRUCK FUEL AND CARBURETION SYSTEMS

Gasoline Specifications—Heavier Grades are Cheaper—Kerosene and Fuel Oil—Special Vaporizers Needed for Kerosene—Benzol Fuel for Gasoline Engines—Liquid Fuel Storage and Supply—Vacuum Tank System—Vacuum Tank Action—Air Pressure System—Packard Fuel System—Principles of Carburetion Outlined—What a Carburetor Should Do—Best Mixture Proportions—Development of Float Feed Carburetor—Elements of Carburetor Design—Venturi Type Mixing Chamber—Packard Carburetor—Packard Governor Construction—Use of Hand Throttle Lever and Accelerator—Packard Fuelizer—Stromberg One Nozzle Type—Stromberg Double Jet—Stromberg Type M Carburetor—Rayfield Mixed Type—Rayfield Adjustment—Rayfield Model O—Zenith Carburetor Construction—Schebler Model A Plain Tube Carburetor—Holley Model K Carburetor—Ensign Carburetor—Cold Weather Starting—Air Cleaner—Methods of Gas Supply Regulation—Hydraulic Governor—Kramer Governor—Pierce Governor—Simplex Governor—Care of Simplex Governor.

Gasoline Specifications.—The Bureau of Mines at Washington has issued tentative specifications for the purchase of gasoline by the Government, and outlines its ideas as follows:

1. Neither the gasoline nor its products of combustion should have a strong or markedly disagreeable odor, this being objectionable to users of motor cars.

2. The gasoline should be free from matter which is not hydrocarbon, such as water, sediment, acid, and so on.

3. The gasoline should be free from bodies which either originally or after combustion attack the metal composing the engine. Acid removed in refining and excessive sulphur content fall under this head.

4. The gasoline should not contain excessive percentages of unsaturated or aromatic hydrocarbon, since some evidence is at hand to indicate that there may be limits in the ability of motors as at present constructed and adjusted, to utilize these products.

5. The gasoline should not contain too high a percentage of very volatile products which tend toward high evaporation losses and excessive danger in handling and storage.

The gasoline should not contain any considerable percentages of heavy or non-volatile constituents which prevent the atomization into engine cylinders of a mixture which can be burned completely.

Heavier Grades Are Cheaper.—At the present time several grades of gasoline are sold, these generally being classified according to their specific gravity, though the distinctive quality is that of volatility. The gasolines with low specific gravity, and generally with low boiling range, sell for the highest prices. Heavier grades are cheaper, and, if properly used, they are capable of developing more power per unit volume than are the lighter gasolines.

The Bureau of Mines has considered it advisable to divide gasoline into three classes, according to the maximum temperature limit in degrees Centigrade below which ninety to ninety-five per cent by volume must distill. The high-grade gasoline is to be used for special purposes, such as for aeroplanes and so on, and should include products of the type now sold in the eastern market as of 70 degrees Beaumé or over. The middle grade is to be used for motor cars of a design, say, two years ago, and is represented by the type of gasoline now sold in the eastern market which ranges from 65 to 70 degrees Beaumé. The third grade, represented by the gasolines now sold in the eastern markets as around 60 per cent Beaumé gravity, is used satisfactorily in up-to-date motor car engines. It is realized that the motor car engine has been improved so that it can use a heavier grade of fuel than was possible a few years ago.

Kerosene and Fuel Oil.—Kerosene oil is now taking a front rank among the fuels for explosive power, and crude petroleum is growing in favor as the most economical explosive-power fuel in use. Kerosene-oil motors are largely in the market and a number of concerns are building motors for crude-oil fuel. A "fuel-oil" (distillate) obtained from the residue after the kerosene has passed over from the still, and a grade cheaper than kerosene, is becoming available as an explosive-power fuel. Kerosene has a variable specific gravity from 0.78 to 0.82, a vapor-flashing point at 120° to 125° F., and the oil ignites when heated to about 135° F., and boils at about 400° F. Its vapor is five times heavier than air and requires about 190 cubic feet of air per pound for its complete combustion, or 76 cubic feet of air per cubic foot of its vapor. Its heat of combustion varies slightly from 22,000 B.T.U. per pound. Fuel-oil (distillate) has an average specific gravity of 0.82 and weighs 7.3 pounds per gallon. Its vapor-flashing temperature is 218° F., and temperature of distillation above 400° F., and it has a heat-unit value of about 18,000 per pound.

Special Vaporizers Needed for Kerosene.—As kerosene forms one of the larger portions of the distillates of crude oil, it is apparent that if this material could be used as fuel for internal combustion engines it might replace gasoline to a certain extent. If considered from a point of view of heat units contained or heating value, kerosene would be a better fuel than gasoline, though considering it with its other disadvantages in mind it is not so suitable for use in existing types of motors. The chief difficulty which retards its use is that it will not vaporize readily at ordinary temperatures, and before it will evaporate sufficiently to form a gas with air it must be heated. This calls for specially constructed vaporizing devices and jacketed manifolds, which will be described in proper sequence. Owing to the low rate of evaporation it is contended that it cannot be used successfully on high-speed motors where flexibility of control is desired and where the engine must be accelerated from its minimum to the highest speed in a short time. On slow and moderate speed motors, such as used for stationary tractor and marine service, kerosene has been employed with some degree of success.

Benzol Fuel for Gasoline Engines.—In England, where gasoline sold for 65 cents a gallon in normal times, or 100 per cent more than the average price in this country, engineers have sought to use benzol which is said to be adaptable to the present type of motors without change, and in cases where it has been used as much power is obtained as with gasoline. This material is a by-product incidental to the manufacture of illuminating gas and coke, and while it was formerly distilled from coal-tar and obtained only in small quantities, improved methods make it possible to produce about three gallons from every ton of coal changed into coke or gas. The former material was at one time produced by a process which permitted the gas to escape, but at the present time this is retained and condensed to form benzol. The crude product is a foul-smelling liquid, which has about the same consistency and color as heavy ale. When subjected to a refining process the dirty liquid is converted to one that is about the same color as water.

Benzol is not as volatile as gasoline, but it is claimed that a motor may be started without difficulty with this fuel supplied to a carburetor of ordinary construction. Owing to the greater number of heat units it contains, it is said it will develop more power than gasoline, and as it will not evaporate so readily it does not become stale or heavy so soon by the vaporization of the lighter fractional constituents. A disadvantage incidental to its use has been that owing to it being richer in carbon than gasoline, it would deposit more of this substance on the piston head and interior of the combustion chamber. While this may be true of poorly refined benzol, and when mixture proportions are not correct, it applies equally well when present low grades of gasoline are used and when the mixture of gasoline vapor and air supplied the cylinders is too rich.

The average carburetor will vaporize benzol at Summer temperature, but starting is harder in cold weather. The carburetors fitted with heating arrangements for air are best, but as this is now almost universal practice in all automobiles owing to the low volatility of the gasoline used, it cannot be advanced as an objection to the use of benzol. In the early experiments carried out in England, it was found that the exhaust valve seats pitted more easily with benzol and air mixtures, but this condition was attributed to the use of improperly refined fuel and the liberation of acid gases during combustion which had a decided chemical effect on the hot valve metal. The price of benzol varies with locality in many communities. In this country it can be obtained ordinarily only at drug stores or from hardware merchants, but in general the average price is higher than gasoline. Combination fuels, consisting of alcohol and benzol, are being marketed in a few sections of the country where these substances are cheaper than gasoline because of local conditions. The Germans made considerable use of such combinations and experimented to determine the most economical proportions to use.

According to our Army Intelligence Reports, many of the German army automobiles were being run on a mixture of benzol and alcohol during the war. As soon as Germany found herself cut off from outside supplies of gasoline, a technical committee was appointed to find a substitute. Experiments were carried out with a Mercedes touring car equipped with an ordinary carburetor, when mixtures of alcohol and benzol were found to give satisfactory results. Summarized, the results obtained in these tests were as follows:

Benzol	Alcohol	Speed Obtained M. p. h.	Miles on 1 Liter of fuel
1 part	1 part	42.2	4.66
1 part	2 parts	41	4.4
1 part	3 parts	39.1	4.3
1 part	4 parts	38.5	4.1
1 part	5 parts	36	3.7
Benzol only		41.6	3.79
Gasoline only		43.49	3.6

Calculating on the rates existing before the war, the benzol-alcohol mixture is the cheapest fuel obtainable. One liter of gasoline costs nine cents, benzol 8.6 cents and alcohol 8.2 cents. The cost per kilometer works out as follows:

	Cents
Gasoline	0.0157
Benzol	0.01362
Alcohol-benzol 50 per cent	0.0125
Pure Alcohol	0.0167

This shows that a fifty per cent mixture of alcohol and benzol is the most economical, and it is this fuel which had been used throughout the German motor transport service when gasoline could not be obtained. The only inconvenience experienced was the necessity of a preliminary heating of the carburetor. Starting the motor was a difficult task, and on several occasions when the army had been retreating, automobiles were abandoned on this account. This difficulty was overcome by the obvious expedient of fitting a supplementary tank containing a small quantity of gasoline or ether. A three-way cock allows the auxiliary tank to be put into connection with the carburetor for starting purposes. As soon as the motor is warm the reserve volatile fuel is shut off and the alcohol-benzol mixture supplied to the motor. In case of a breakdown near the enemy's lines, or the loss of the main fuel supply through a bullet or piece of shell piercing the tank, the reserve supply was used. This was enough to take the vehicle ten or twelve miles, which was generally sufficient to remove it from the danger zone.

Liquid Fuel Storage and Supply.—The problem of gasoline storage and method of supplying the carburetor is one that is determined solely by design of the truck. While the object of designers should be to supply the fuel to the carburetor by as simple means as possible, the fuel supply system of some trucks is quite complex. The first point to consider is the location of the gasoline tank. This depends upon the amount of fuel needed and the space available in the truck body.

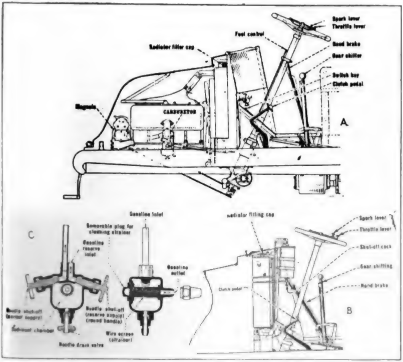

Spark lever
Throttle lever
Fuel control
Radiator filler cap
Hand brake
Gear shifter
Switch key
Clutch pedal
Magneto
CARBURETOR
A
Gasoline inlet
Removable plug for cleaning strainer
C
Gasoline reserve inlet
Gasoline outlet
Needle shut-off (normal supply)
Sediment chamber
Needle shut-off (reserve supply) (round handle)
Wire screen (strainer)
Needle drain valve
Radiator filling cap
Spark lever
Throttle lever
Shut-off cock
Gear shifting
Hand brake
Clutch pedal
B

Fig. 84.—Fuel Supply of International Harvester Motor Truck. The View at A Shows a Gravity Tank. That at B Outlines Use of Vacuum Tank, While Special Fuel Filter is Shown at C.

A very simple and compact fuel supply system is shown at Fig. 84, A, which represents a simplified view of the motor compartment of the International Harvester truck. The power plant in this light truck is a small four-cylinder engine of comparatively low power and correspondingly low fuel consumption. As it does not require much gasoline to run a small engine, one can obtain a satisfactory operating radius on one filling of

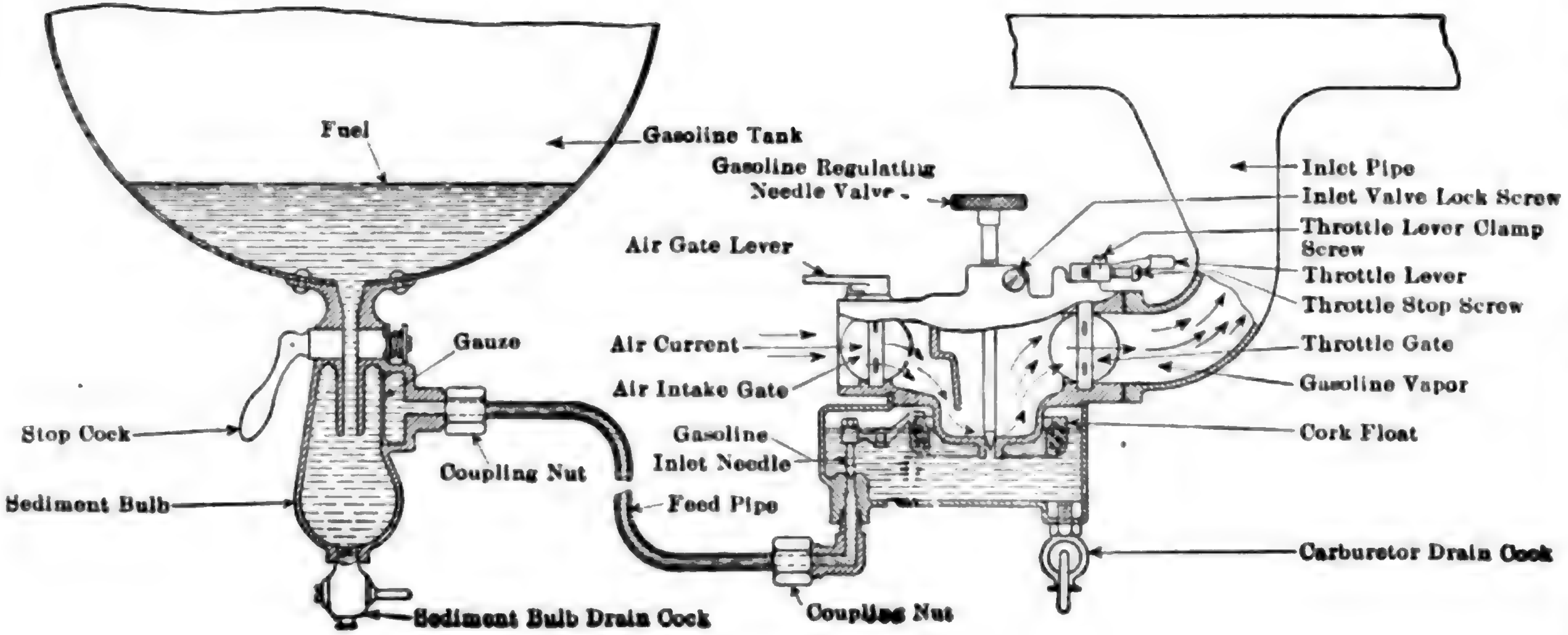

Fuel
Gasoline Tank
Gasoline Regulating Needle Valve
Air Gate Lever
Inlet Pipe
Inlet Valve Lock Screw
Throttle Lever Clamp Screw
Throttle Lever
Throttle Stop Screw
Throttle Gate
Gasoline Vapor
Cork Float
Carburetor Drain Cock
Gauze
Air Current
Air Intake Gate
Gasoline Inlet Needle
Stop Cock
Coupling Nut
Sediment Bulb
Feed Pipe
Sediment Bulb Drain Cock
Coupling Nut

Fig. 85.—The Ford Model T Fuel Supply and Gas Making System Showing Simple Form of Carburetor.

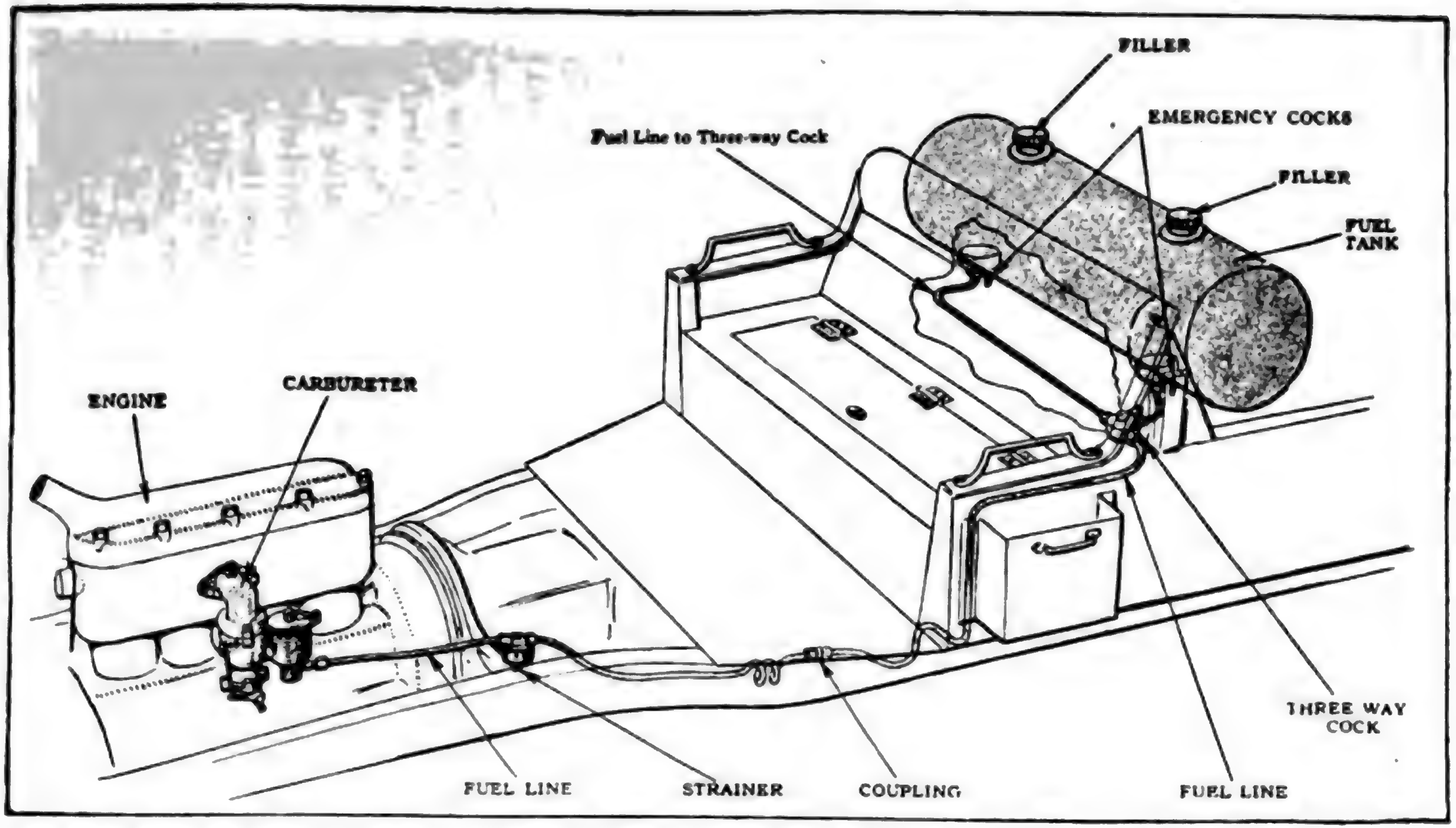

FILLER
EMERGENCY COCKS
Fuel Line to Three-way Cock
FILLER
FUEL TANK
ENGINE
CARBURETER
THREE WAY COCK
FUEL LINE
STRAINER
COUPLING
FUEL LINE

Fig. 86.—Fuel Supply System of Dodge Light Truck Showing Application of Supply Tank to Obtain Gravity Feed.

a comparatively small tank. In this instance the fuel container is suspended from the dashboard and is placed immediately back of it, the dash separating it from the engine cylinders. The carburetor, which is carried as indicated, is joined to the tank by a short piece of copper tubing. This is the simplest possible form of fuel supply system. A special form of combined strainer and shut-off fitting is supplied that permits of drawing the gasoline from two levels in the tank. One portion serves as a regular source of supply; that below it serves as a reserve supply. The fuel system used on the Ford light delivery wagon and truck shown at Fig. 85 is a simple gravity feed, as the tank carried under the seat is raised a sufficient height to insure positive supply of fuel. In the Dodge light army truck, the tank was carried back of the seat, as at Fig. 86.

In some cases, even when the fuel container is carried under the seat, as at Fig. 87, it cannot be placed high enough to obtain positive supply by gravity head. In this case, two methods of forcing fuel flow are possible. In one, as shown at Fig. 84, B, and Fig. 87, a vacuum tank is placed on the dash; in the other, pressure feed by air pumped into the tank to displace the fuel is employed.

Vacuum Tank System.—The vacuum tank system is very popular at the present time and is used on most of the modern passenger automobiles, but is not as widely used on trucks where the simpler gravity feed systems are favored. The tank is carried under the seat or at the rear of the dash, and fuel is drawn by the engine suction from the main container to the auxiliary tank shown at Fig. 88. The float mechanism interrupts the vacuum feed when the tank is sufficiently full by shutting off the suction pipe and opening an atmospheric valve that lets in air to break the partial vacuum. It requires considerable movement of the float to trip the lever F and change the relative position of the suction valve A and the atmospheric valve B. When B is seated, A is open and the engine draws gasoline into the upper or float chamber. When A is seated, B is open and the transfer of fuel from main container to auxiliary tank ceases. The simplicity of the mechanism is such that there is little possibility of trouble.

Engine suction through pipe C draws gasoline through pipe D into the upper chamber, and when the float G has risen to the top suction is cut off by the valve A and no more fuel flows.

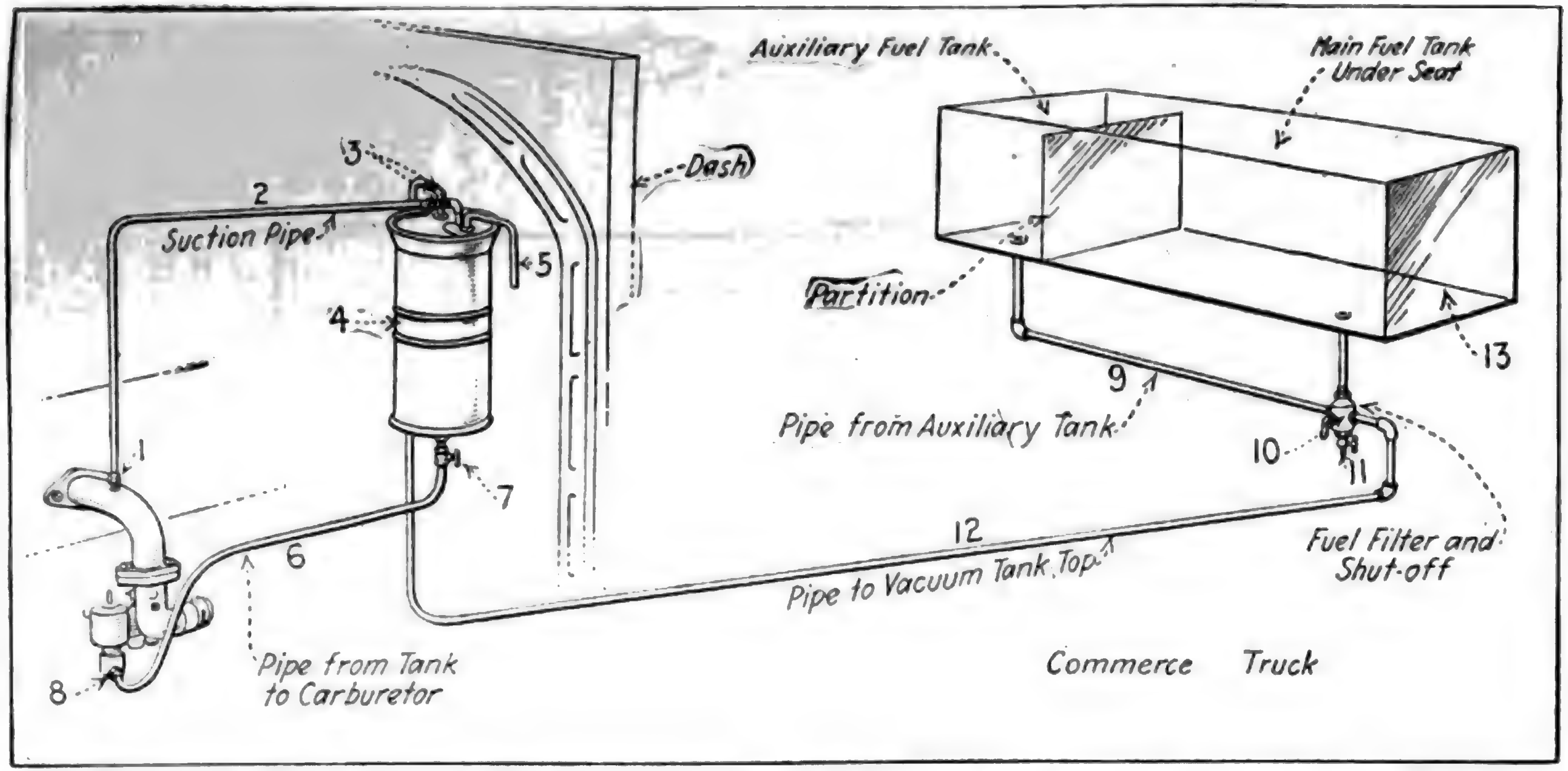

Auxiliary Fuel Tank
Main Fuel Tank Under Seat
Dash
3
2
Suction Pipe
5
4
Partition
13
9
Pipe from Auxiliary Tank
10
11
1
7
12
6
Fuel Filter and Shut-off
Pipe to Vacuum Tank Top
Pipe from Tank to Carburetor
8
Commerce Truck

Fig. 87.—Fuel Supply System of the Commerce Truck Showing Fuel Feed by Vacuum Tank, Also the Method of Having Main Tank Divided in Two Compartments, the Smaller One of Which is Reserved for Emergency.

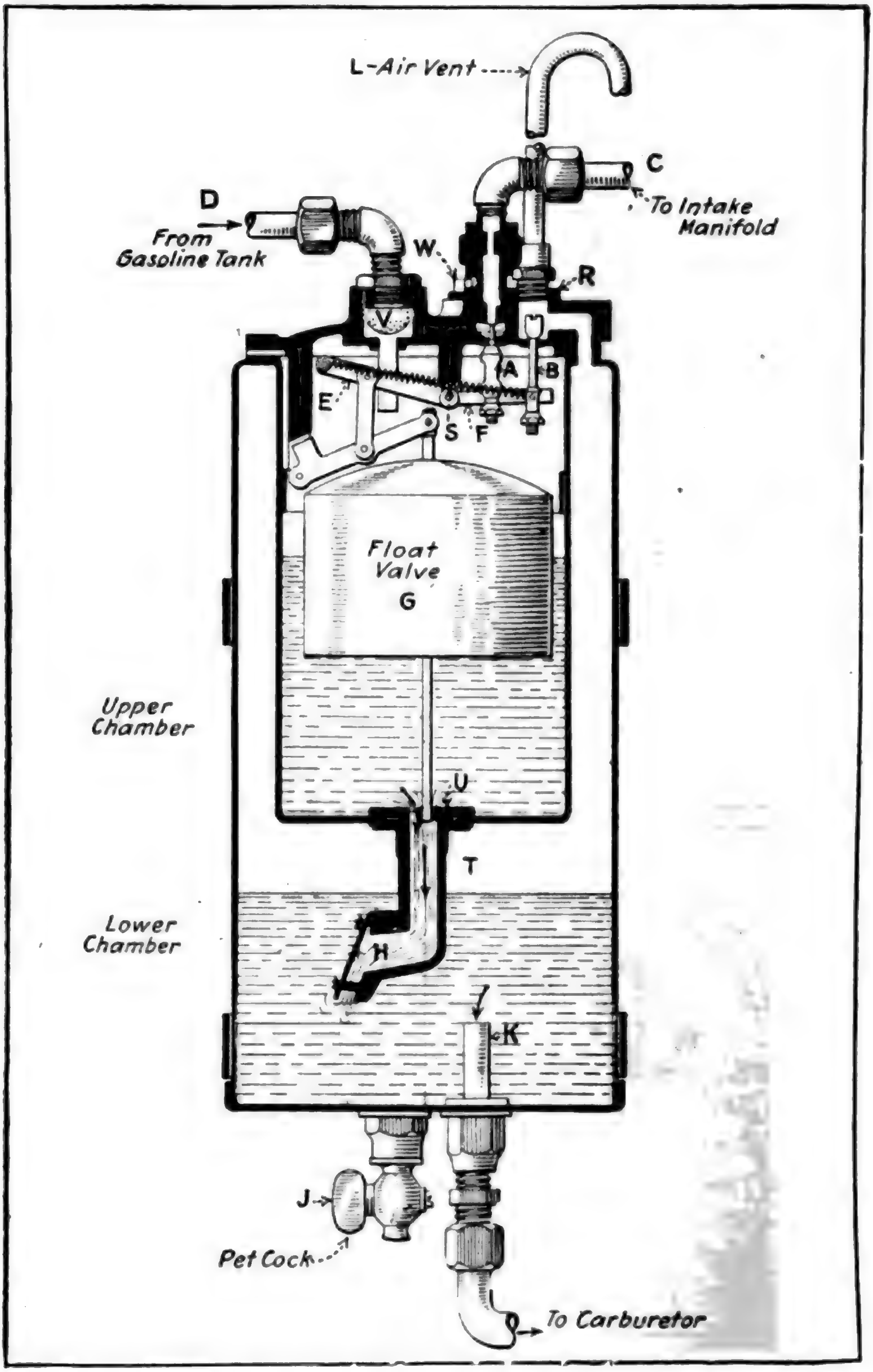

L-Air Vent
C
To Intake Manifold
D
From Gasoline Tank
W
R
V
A
B
E
S
F
Float Valve G
Upper Chamber
U
T
Lower Chamber
H
K
J
Pet Cock
To Carburetor

Fig. 88.—Sectional View Showing Interior Arrangement of Vacuum Feed Fuel Supply Tank.

Valve B is then opened, allowing atmospheric pressure to enter the chamber; the fuel then drops through the check valve H to the lower chamber, which is always under atmospheric pressure, through air vent R, and is then fed to the carburetor by gravity through pipe K in an uninterrupted flow.

It is very unlikely that it will ever be necessary to open tank, but if it is opened, then follow directions carefully. Before proceeding to repair the vacuum tank make absolutely sure that the trouble is not due to faulty conditions elsewhere by removing connections of pipe D to tank. See if screen V (Fig. 88) is not clogged. Examine closely other causes for trouble of a like nature, such as loose gasoline lines, designated as D and C. Follow line D very carefully from main gasoline tank to vacuum tank and inspect all connections; also see that line C from vacuum tank to engine intake has no loose fittings. If, however, after examining all other causes which would likely make trouble, you have satisfied yourself that there is trouble in vacuum tank, there are several tests you can make before disassembling tank which can be very easily made as follows:

Open petcock J at bottom of vacuum tank—if there flows out one-sixth of a pint or more of gasoline your trouble is not in the tank. To test flapper valve H, plug up air vent R, then detach tubing from bottom of tank to carburetor, start motor by using the starter and apply finger to the opening. If suction is felt continuously, then it is evident that flapper valve H is being held off its seat and is letting air into the chamber. To remedy this trouble proceed as follows: Remove plug W in top and squirt a little gasoline into the tank, which will wash sediment off valves and moisten them. This should cause tank to work immediately. If it does not it will be necessary to remove top from tank by loosening the eight screws. When you have taken out screws the utmost care should be taken in removing top from tank so as not to damage gasket, as it is very necessary when replacing that this joint be absolutely airtight. After taking cover off lift out the inner tank. The flapper valve will be found screwed into the bottom of this inner tank and may have sediment on it, which can be scraped off with knife. Valves, levers and springs are fastened on top.

Air Pressure System.—The pressure feed method of fuel supply is well exemplified by the Packard system which is clearly outlined at Fig. 89, which shows the main elements of the fuel

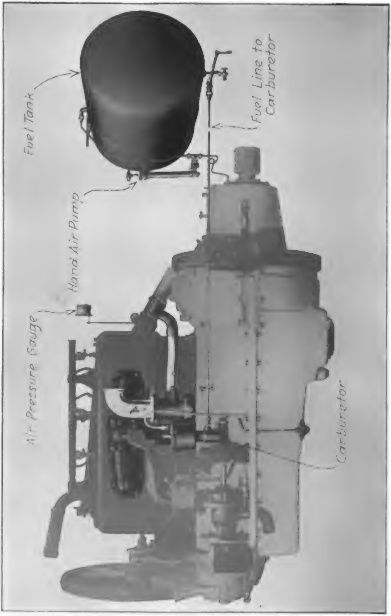

Fuel Tank
Fuel Line to Carburetor
Hand Air Pump
Air Pressure Gauge
Carburetor

Fig. 89.—Showing Fuel System of Packard Truck in Which the Fuel Flow is Produced by Air Pressure in the Gasoline Tank.

group. The gasoline flow is due to the displacement of the liquid by air pressure, an engine-driven pump insuring the maintenance of constant air supply to replace the fuel burned in the engine. A hand pump serves for pumping air when the engine is not functioning, as fully explained in the description of the Packard fuel supply system which follows.

Packard Fuel System.—The gasoline tank, located under the seat, is of heavy gauge tinned steel. In filling the tank, pour the gasoline through a chamois skin to free it from water and impurities, but in doing so make sure that the side of the funnel makes a firm contact with the gasoline tank. Gasoline and chamois, when brought into contact, form static electricity, which may cause a jump spark unless the funnel is grounded to the tank.

The gasoline tank capacities are as follows:

Model	Capacity
1-ton	16½ gallons
1½-ton	16½ gallons
2-ton	16½ gallons
3-ton	21 gallons
4-ton	21 gallons
5-ton	27 gallons
6-ton	27 gallons

The gasoline shut-off is located under the gasoline tank at the left side. Near each end, on the bottom of the gasoline tank, are draincocks. These can be used for draining off gasoline or any sediment that has accumulated in the tank.

The flow of gasoline from the tank to the carburetor on all models is maintained by air pressure. The air pressure is furnished by an air pump, located on the right side of the motor crankcase. This pump is driven from the camshaft. It draws air from outside the crankcase and forces it under pressure past the relief valve in the pump body to the gasoline tank. The hand or emergency pump on the dash provides means of obtaining initial air pressure before the motor is started. It is used when the gauge on the dash shows that there is no air pressure in the gasoline tank. The plunger leather of this pump should be oiled occasionally with neat's-foot oil. Mineral oils improve the operation of the pump only temporarily and tend to dry up the leather. When a truck has been standing over night or the motor becomes cool, an initial flow of gasoline may be obtained by a few strokes of the hand pump. The hand pump stopcock handle should be turned up when the pump is not in use. To obtain pressure by the hand pump, turn the stopcock handle toward the rear and operate pump until pressure shows on gauge. To prevent leakage of air from the gasoline tank, the filler cap should always be screwed down tightly by hand but should never be hammered.

Principles of Carburetion Outlined.—The process of carburetion is combining the volatile vapors which evaporate from the hydrocarbon liquids with certain proportions of air to form an inflammable gas. The quantities of air needed vary with different liquids, and some mixtures burn quicker than do other combinations of air and vapor. Combustion is simply burning, and it may be rapid, moderate, or slow. Mixtures of gasoline and air burn quickly; in fact, the combustion is so rapid that it is instantaneous, and we obtain what is commonly termed an "explosion." Therefore, the explosion of gas in the motor truck engine cylinder which produces the power is really a combination of chemical elements which produce heat. If the gasoline mixture is not properly proportioned, the rate of burning will vary, and if the mixture is either too rich or too weak the power of the explosion is reduced and the amount of power applied to the piston is decreased proportionately.

What a Carburetor Should Do.—While it is apparent that the chief function of a carbureting device is to mix hydrocarbon vapors with air to secure mixtures that will burn, there are a number of factors which must be considered before describing the principles of vaporizing devices. Almost any device which permits a current of air to pass over or through a volatile liquid will produce a gas which will explode when compressed and ignited in the motor cylinder. Modern carburetors are not only called upon to supply certain quantities of gas, but these must deliver a mixture to the cylinders that is accurately proportioned and which will be of proper composition at all engine speeds.

Flexible control of the engine is sought by varying the engine speed by regulating the supply of gas to the cylinders. The power plant should run from its lowest to its highest speed without any irregularity in torque, i.e., the acceleration should be gradual rather than spasmodic. As the degree of compression will vary in value with the amount of throttle opening, the conditions necessary to obtain maximum power differ with varying engine speeds. When the throttle is barely opened the engine speed is low and the gas must be richer in fuel than when the throttle is wide open and the engine speed high.

When an engine is turning over slowly the compression has low value and the conditions are not so favorable to rapid combustion as when the compression is high. At high engine speeds the gas velocity through the intake piping is higher than at low speeds, and regular mixture is insured by the higher suction, and better combustion is secured because of the higher compression and fuller charges.

Best Mixture Proportions.—Gasoline vapor uniformly mixed with about sixteen times its weight of air produces a strongly explosive mixture. A little more air makes a little less powerful charge but is slightly more economical in the amount of gasoline used. As more ~~gas~~ air is used the mixtures produced burn more and more slowly, with less power and reduced economy until a point is finally reached where the mixture is too weak to ignite.

If we start again at the 16 to 1 mixture and reduce the proportion of air, we find that the power holds up or even increases for a slight range, after which it falls off as the mixtures produced grow richer, until finally the limit is reached at which the charge will not ignite. These rich mixtures do not contain air enough to completely burn the gasoline and naturally are not economical, besides having a tendency to soot up the inside of the cylinder and cause trouble. If very rich, black smoke will show in the exhaust and a rank smell is produced. The weaker mixtures, having an excess of air, burn clean and, being more economical, are to be preferred.

A carburetor adjustment giving a mixture a little weaker than the most powerful one, but not so weak as to cause backfiring, or a popping noise in the carburetor, is the best and most economical.

Development of Float-Feed Carburetor.—The modern form of spraying carburetor is provided with two chambers, one a mixing chamber through which the air stream passes and mixes with a gasoline spray, the other a float chamber in which a constant level of fuel is maintained by simple mechanism. A jet or standpipe is used in the mixing chamber to spray the fuel through and the object of the float is to maintain the fuel level to such a point that it will not overflow the jet when the motor is not drawing in a charge of gas. Two very early forms of float-feed carburetor are shown at Fig. 90. That at A is the original Maybach form and one of the earliest carburetors of this type evolved. There was no adjustment for the air or fuel, so the form shown at B was devised later, which incorporated

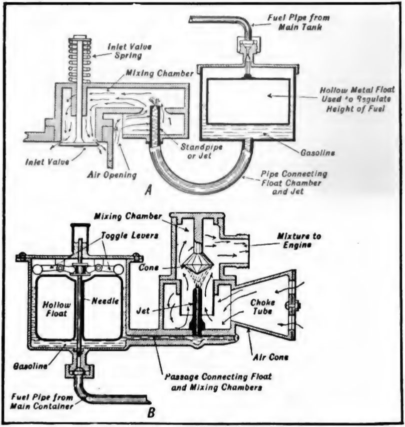

Fuel Pipe from Main Tank
Inlet Valve Spring
Mixing Chamber
Hollow Metal Float Used to Regulate Height of Fuel
Standpipe or Jet
Gasoline
Inlet Valve
Air Opening
Pipe Connecting Float Chamber and Jet
A
Mixing Chamber
Toggle Levers
Mixture to Engine
Cone
Hollow Float
Needle
Jet
Choke Tube
Gasoline
Air Cone
Passage Connecting Float and Mixing Chambers
Fuel Pipe from Main Container
B

Fig. 90.—Early Float Feed Carburetors. A—Maybach's Design. B—Phoenix Daimler Modification of Maybach's Design.

a number of improvements. The float and mixing chambers were cast together instead of making them separate and joining them by pipe, as shown at A. The float construction was improved and the gasoline shut-off valve was operated through leverage instead of being directly fastened to the float. The spray nozzle was surrounded by a choke tube which concentrated the air stream around it and made for more rapid air flow at low engine speeds. A conical piece was placed over the jet to break up the entering spray into a mist and insure more intimate admixture of air and gasoline. The air opening was provided with an air cone which had a shutter controlling the opening so that the amount of air entering could be regulated and thus vary the mixture proportions within certain limits.

Elements of Carburetor Design.—The design of components of modern carburetors differ largely, but most of the modern mixing devices operate on the same general principle. Certain features of design have been accepted in many cases, such as automatic mixture compensation by auxiliary air valves, Venturi type of mixing chamber, float and mixing chamber concentric, separate adjustment for gasoline and air, and simplicity of construction. Various carburetors have been devised of late in which auxiliary air valves are done away with and proper compensation for mixture variation due to various engine speeds is made by ingenious applications of double jets. In some, manual regulation of the incoming air is again resorted to.

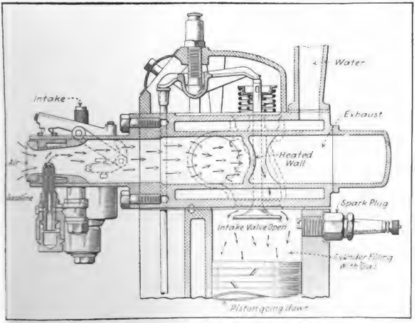


Fig. 91.—**Diagram Showing Action of Float Feed Carburetor Showing How Descending Piston Draws a Mixture of Gasoline and Air into the Cylinder of the Engine Through the Open Intake Valve.**

Automatic compensation is made necessary because a satisfactory mixture must be furnished at all engine speeds without the operator constantly varying the fuel supply or air proportions to allow for different conditions of operation produced by varying speeds. On early types of carburetors it was necessary to constantly vary the mixture proportions by working the air shutter or fuel valve from the driver's seat while the vehicle was in motion. The aim was to secure a mixture that was best adapted to the conditions of operation then present, and while a skillful driver would manipulate the adjustments in a way to deliver well-proportioned mixtures to the cylinder, the average operator did not control the mixture exactly and the results obtained did not make for maximum efficiency at all times.

The writer has described the process of carburetion, and it is evident that the gas is supplied the cylinder by the pumping effect of the piston, as shown at Fig. 91. The velocity of the entering gases depends upon engine speed, and as the draught diminishes it will not pick up as much fuel as when it is traveling at a higher rate. The present type of compensating carburetor provides for a sufficiently rapid flow of gas at low speed by constricting the mixing-chamber bore at the spray nozzle so that the gas speed will be sufficiently high when the engine is pumping slowly. The reduced diameter of the mixing-chamber increases the velocity of the gases because the cylinder must be filled through a smaller hole in a certain unit of time than would be the case if the bore were larger. Therefore, to insure a full supply reaching the cylinder, the gases must pass the top of the jet at a high rate of speed even if the piston is working slowly. As the opening is constricted, not enough air will be drawn in at high speed, and it is necessary to supply it through an auxiliary opening usually controlled by some automatic form of valve. This can be adjusted to open only when the suction effect is sufficiently high to overcome the tension of the spring which holds the valve to the seat, and this increased suction effect obtains only at high speeds.

Venturi Type Mixing Chamber.—The Venturi type of mixing chamber is one thing which is being widely used at the present time, because it has properties, when properly proportioned, of insuring high gas velocity at low engine speed. Special care must be taken in the proportions of the air passage, as it is necessary that the area be large enough to allow the air stream to pass through freely, yet at the same time it must be constricted to such a point that the entering air stream will pass the top of a standpipe with sufficient momentum to draw an adequate supply of gasoline from the spray nozzle. The velocity of the air stream has been variously estimated, but most authorities are agreed that it should be from 7,000 to 9,000 feet per minute to insure picking up a sufficient amount of liquid as it passes around the spray nozzle.

Packard Carburetor.—A number of best known motor truck manufacturers employ carburetors of their own make instead of the product of carburetor makers. A good example of one of these which has been developed especially for the Packard engine is shown at Fig. 92. The gasoline enters the carburetor float chamber through a needle valve in the usual manner, and the movement of the float regulates the incoming flow of gasoline by means of balance levers. The gasoline level in the float chamber should be one-eighth inch below the top of the spray nozzle. The mixing chamber is a cylindrical member around and above the spray nozzle. It is surrounded by a water jacket, through which warm water passes from the engine circulation system. An auxiliary air valve controlled by springs admits the surplus air needed at full throttle opening. The primary air inlet is sufficiently large to supply air for all running ordinary conditions and the auxiliary air valve opens very slightly at low engine speeds.

The primary air intake takes air from a stove which is on the exhaust pipe at the rear of the right side of the motor. This provides a supply of warm air which prevents condensation of the gasoline in cold weather. The proportion of warm and cold air may be regulated by an adjustable valve located behind the carburetor in the primary air passage. The auxiliary air valve is in a housing at the rear of the carburetor, and it is controlled by the tension of two springs, one within the other. These springs are regulated by the auxiliary air valve lever on the control board. If the air valve lever is moved toward "gas" the spring tension is increased and a rich mixture is provided. If it is turned toward "air" a lean mixture is obtained because the spring tension is reduced. If the air valve lever is turned too far toward "air" the consequent lean mixture may cause "spitting back" into the carburetor. If it is turned too far toward "gas," the consequent rich mixture may cause irregular running and

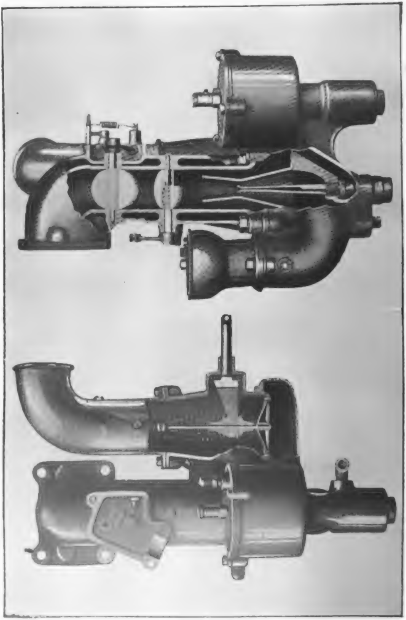


Fig. 92.—Sectional View Showing Construction of Packard Motor Truck Carburetor.

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overheating. When spitting occurs in carburetor, move air valve lever one notch at a time toward "GAS" until spitting stops. Experience will dictate the proper position for efficient running. When the choke button is pulled out for starting motor, both the primary and auxiliary air valve should be completely closed.

To adjust the auxiliary air valve proceed as follows: Disconnect the clevis from the air valve wedge stem and set the wedge so that the notch on wedge stem is flush with the end of the air valve wedge guide. With the wedge in this position the outer air valve spring should just bring the valve firmly to its seat. Adjust the lower pair of check nuts on the air valve stem so that the valve may be depressed $\frac{7}{32}$ of an inch before the lower nut comes into contact with the top of the inner air valve spring and lock in this position. Place the air and gas lever on the control board three notches toward air from the center position and adjust the connecting rod clevis to connect with the air valve wedge when the notch in the stem is flush with the end of the air valve wedge guide.

To facilitate starting in cold weather, there are shutters in both primary and auxiliary air intakes. These shutters are operated by pulling out the button under left side of front bumper. After motor starts, this button should be immediately pushed back into position. Where electric starter is used the shutters are operated by the button which is placed in center of control board.

The governor throttle valve is the upper butterfly valve located in the mixing chamber. It is directly connected with the centrifugal governor, described below. The governor throttle valve mechanism, which is set and sealed at the factory, allows the motor to run at 1,075 revolutions per minute with main throttle valve wide open. The main throttle valve is independent of the governor throttle valve, but is similar in design and is below it in the mixing chamber. It is controlled by the accelerator pedal and by the hand throttle lever. This throttle does not regulate the quality or the richness of the mixture, but simply the amount supplied to the cylinders within the limits of the governor throttle valve.

Packard Governor Construction.—The governor is of the centrifugal type and is located on a shaft attached to the water pump driving gear. It is enclosed within a housing attached to the cover of the motor gear compartment. The governor consists of two weighted balls hinged on a bracket on the water pump driving shaft. The centrifugal action of these balls controls their position and actuates a connecting rod which projects through the water pump shaft and through suitable linkage and connections operates the governor throttle valve. All governor connections and parts are enclosed and sealed to prevent their being damaged or tampered with by unauthorized persons.

The operation of the governor controls the position of the governor throttle valve which regulates the motor speed and, consequently, the maximum speed of the truck. When the motor is running at speeds below the point at which the governor cuts in, springs hold the weighted governor balls close to the shaft. With the balls in this position the governor throttle valve is wide open. The governor is set to maintain a correct maximum motor speed of 1,075 r.p.m., which is equivalent to the following standard truck speeds:

Model	Speed
1-ton	16 M. P. H.
1½-ton	16 M. P. H.
2-ton	14 M. P. H.
3-ton	12 M. P. H.
4-ton	12 M. P. H.
5-ton	11 M. P. H.
6-ton	11 M. P. H.

The governor adjustment is not intended as a means of raising the maximum speed of the truck above the standard speeds for which it is set.

Caution.—The governor will not control the speed of the truck when descending steep grades. Extreme care should be exercised by the driver not to overspeed while coasting.

Use of Hand Throttle Lever and Accelerator.—Either the hand throttle lever or the accelerator pedal may be used to control the speed of the truck within the limits set by the governor. The accelerator pedal is the usual means for controlling the speed of the truck below the maximum speed allowed by the governor. It will be found convenient while shifting gears or operating the truck with the hand throttle lever set for idling. When the accelerator pedal is released the motor resumes the speed determined by position of hand lever. To control speed by means of hand throttle lever move it to position where desired speed is obtained. To maintain maximum speed set to a point beyond where governor cuts in. With throttle lever wide open there should be a clearance of ⅛ inch to 3/16 inch between the toe board and accelerator pedal.

An adjustable stopscrew holds the hand throttle valve open, and thus allows a small amount of mixture to reach the motor cylinders, even when the throttle lever on the control board is in closed position. This supplies the minimum amount of fuel for idling the motor. To increase the minimum speed, loosen the check nut and turn the stopscrew in. To decrease the speed, turn the screw to rear. This screw is adjusted and sealed at the factory, and there is ordinarily no occasion to change its adjustment.

The Packard Fuelizer.—The woes that beset motors have been gradually increasing as the quality of the fuel on which they were required to run has decreased. Under average running conditions, kerosene splatters about in the cylinders. It removes the film of protecting oil from the walls; some of it collects and burns, turning to carbon that fouls the engine, and the remainder runs down past the pistons and dilutes the lubricating oil in the crankcase.

Engineers have agreed that this condition could be remedied only by providing for complete combustion of the fuel in the cylinders, and the Packard Experimental Laboratories have brought forth a new device called the Fuelizer to adapt Packard engines to the fuels obtainable to-day—and to-morrow. According to Col. J. G. Vincent, vice-president of engineering of the company, the Fuelizer not only assures a clean engine, but it also eliminates all trouble in connection with starting the motor in cold weather. Tests show that a motor equipped with the new device is ready for high gear work on a summer setting of the carburetor within twenty seconds after cranking, regardless of the temperature.

During the past few years automobile manufacturers have spent much time and money trying to meet the threat of decreased quantity of gasoline, due to the great expansion of the industry and the consequent drain on the oil reserves of the country. The experiments centered about the idea of heating the charge as it passed into the engine, and the most common device was the exhaust heated intake. This system provided the engine with no heat when it was starting, slight heat when it was idling, and a maximum of heat when the engine least needed it. A complete reversal of this process was the aim of L. M. Woolson, the engineer who developed the Fuelizer.

The Fuelizer, as it has been perfected to become a standard part of the Packard motor cars, gives the maximum heat to the charge when the engine is starting and idling, and drops out of operation when the engine is able to supply its own heat. It gives complete combustion of the fuel in the cylinders, and during the months of test there was not a single instance of engine fouling.

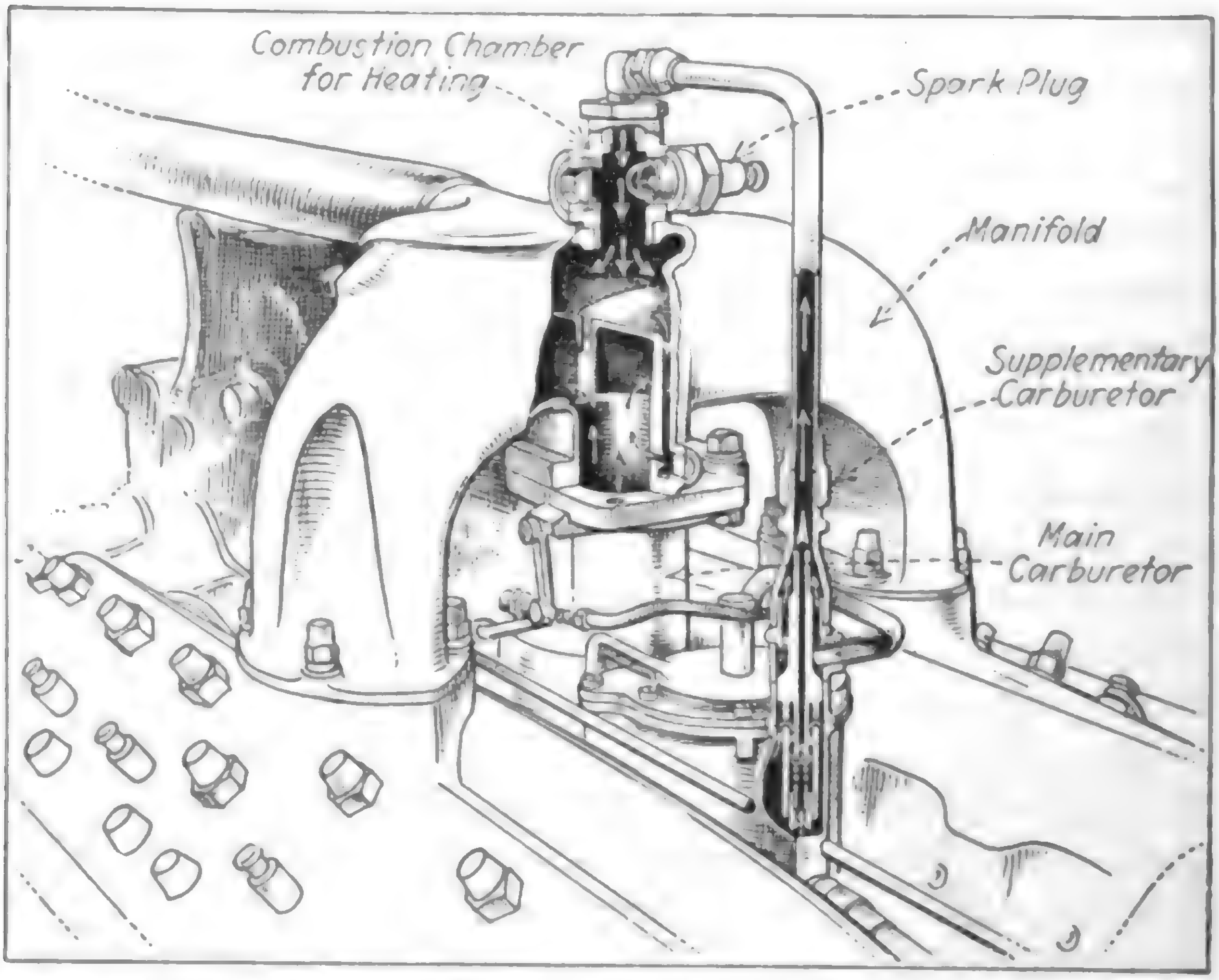


Fig. 92A.—The Packard Fuelizer as Applied to Twin Six-Passenger Car Engine.

The Fuelizer consists of a small supplementary carburetor and a burning chamber where the gas from the little carburetor is burned. This chamber is situated in the intake manifold. When the gas enters, it is ignited by a regulation spark plug and passes into the fresh charge going from the carburetor to the cylinders. The heat of the burned gas changes the wet, poorly carbureted mixture to a dry vapor, which explodes with full efficiency when it is touched off by the spark in the cylinder.

The action of the Fuelizer is entirely automatic, without involving a single moving part. When the engine is starting the

Fuelizer is in full operation, and the heat supplied to the charge becomes less as the throttle is opened. This regulation is provided for by an air valve similar in operation to the air valve of the main carburetor.

Through a small Pyrex glass window the operation of the Fuelizer may be seen. A perfect mixture produces a purple flame, a fairly rich mixture produces a bluish-green flame, and an exceedingly rich mixture is indicated by yellow streaks in the flame.

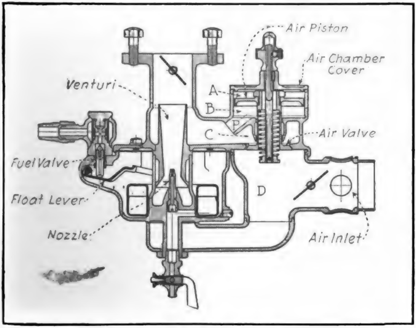


Fig. 93.—Stromberg Single Jet Carburetor.

Stromberg One-Nozzle Type.—The features of the new Stromberg are the balanced air valve, which, if its action were not known, would be referred to as an auxiliary air valve, and the method of using the air which is taken through the air valve in such a way as to give, with a single nozzle, the gasoline flow previously obtained with separate low-speed and high-speed nozzles. Briefly, the balanced valve in operation diverts a portion of the air flow taken through the main inlet, and this diverted air passes through the carburetor body to a point at the upper end of the Venturi tube. The air passage at this point is formed like the entrance for a large Venturi tube, and acts in such a way as to cause the air which has entered through the balanced valve to exert additional suction in the primary Venturi tube. This additional suction and the added gasoline feed are in proportion to the auxiliary air admitted, so that while there is only one nozzle and one air inlet, there are really two air currents exerting a compound action on the gasoline jet. By studying the cross-sectional diagram of this new instrument, given at Fig. 93, the action when in operation will become clear. The single nozzle is shown located in the lower portion of the Venturi tube around the base of which is the brass float operating a fuel valve in the conventional way. The portion of the instrument to the right of the balanced valve is not new to Stromberg practice. However, the balanced valve shown in the upper right of the illustration is new construction.

The mechanism consists of a sleeve having at its lower end the valve proper and at its upper end a piston about twice the size of the valve, so that the piston and valve move together. Within the sleeve is a spring held in place by a rod and nut, which holds the valve up to its seat. It will be noticed there is a small passage P, which connects the chamber B above the valve with C below it. The chamber A above the piston always contains air under atmospheric pressure, except when the dash control valve or air intake shutter is used, because of its communication with the chamber D through the space around the spring and up through the valve sleeve. The vacuum in B is substantially the same as that in C, which is, of course, determined by the demand of the motor and the strength of the air valve spring. A light spring is used so that this vacuum is always very small, perhaps eight ounces. As a result the air valve tends to move upward by difference in pressure between C and D, while the piston tends to move downward by the difference in pressure between A and B. As the piston is approximately twice the area of the valve, the whole valve opens downward, but the balance between the chambers is such that the pulsations of motor suction are deadened and the valve flutter thus eliminated.

When the carburetor is in action and the engine running idle, the valve is slightly off its seat. The single nozzle feeds the gasoline and the primary Venturi supplies nearly all the air. As the engine speed is increased or the throttle opened, a greater demand is made on the air valve, which opens, admitting additional air. When this additional air reaches the top of the Venturi it increases the suction in the Venturi and draws additional fuel, so that the supply taken is in proportion to the amount of air which passes through the valve. In other words, as the air valve opens there is an increase in the supply of gasoline as well as the air sent to the motor, thus the result obtained is like that given by a carburetor with two fuel nozzles and two air inlets.

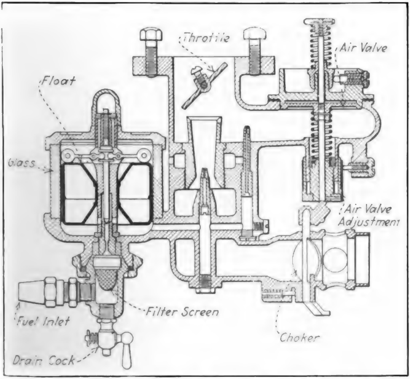


Fig. 94.—Sectional View Showing Stromberg Double Jet Carburetor.

The balanced valve does not flutter, but operates gradually as the pressures vary. At low engine speeds the position of the valve regulates the mixture, but above twenty-five miles an hour, according to the Stromberg engineers, the valve may be open all the way without noticeably affecting the running of the engine except to admit a slightly greater charge. In practice only hot air is used, and it is taken from a tube connecting with a stove surrounding a portion of the exhaust manifold.

Stromberg Double Jet Carburetor.—The carburetor which is shown at Fig. 94 is used on the F. W. D. trucks, and is supplied with fuel through a pipe leading from the gasoline tank behind the driver's seat. It passes into the carburetor below the float chamber, through a small strainer, which may be removed for cleaning by unscrewing gasoline line union. The flow continues through the needle valve to the float chamber. A metal float maintains the proper level of fuel through the action of two weighted levers, which control the action of the needle valve.

When the engine is idling, air is drawn in through the primary intake, passing around the primary nozzle C, from which a jet of gasoline is spraying. Under load, the air valve E allows additional air to be sucked in past auxiliary nozzle J, producing a mixture which unites with the primary mixture formed in the Venturi tube, above nozzle C, and passes by throttle valve.

Cleaning.—Both primary and auxiliary nozzles may be reached for cleaning in case they become clogged with particles of foreign matter by taking out the plugs P and A P.

The high-speed adjusting nut B and the low-speed adjusting nut A control the only adjustments of mixture. With the motor at rest, set the high-speed nut B so there is at least one-sixteenth of an inch clearance between the spring G and the nut X above it. This is imperative. Do not adjust carburetor until motor is thoroughly warmed up. When the motor is warm and with spark retarded, adjust nut A up or down until motor runs smoothly at low speed. To determine proper adjustment, open the air valve with finger by depressing X slightly. If, when so doing, motor speeds up noticeably, it indicates too "rich" a mixture, and A should be turned down notch by notch. If, on the other hand, motor dies suddenly when slightly opening the air valve, it indicates too "lean" a mixture and A should be turned up until this is overcome. Once properly set for idling, do not change this adjustment when making the high-speed adjustment.

Advance the spark to normal position and open the throttle gradually. If motor backfires through the carburetor, it is a positive indication of too "lean" a mixture, and nut B should be turned up notch by notch until this is overcome. If mixture is too "rich," as indicated by a loading of the motor and heavy, black smoke from the exhaust, turn B down until motor operates properly. A further test for the correct mixture at high speed can be made by depressing air valve when the engine is running at this speed. If, when so doing, motor speeds up, it

indicates too "rich" a mixture; if motor runs slower, too "lean" a mixture. Turning either adjusting nut up means a richer mixture or more gas. Down means a leaner mixture or more air.

Stromberg Type M Carburetor.—The carburetor shown at Fig. 95, and in section at Fig. 96, differs from older styles in that it is a Plain Tube type, having the air passages fixed in size, while the gasoline is automatically and accurately measured by the air flow itself, at all speeds and loads. The mixture proportion is maintained constant by the "air bled nozzle" construction, in which a small amount of air is mixed with the gasoline before it reaches the jets. There are two adjustments, the high speed and the extremely low speed or idle. The high speed is controlled by the needle A, past which point is taken all the gasoline at all speeds. Turning A to the left, anti-clockwise, gives more gasoline. To the right, or clockwise, less.

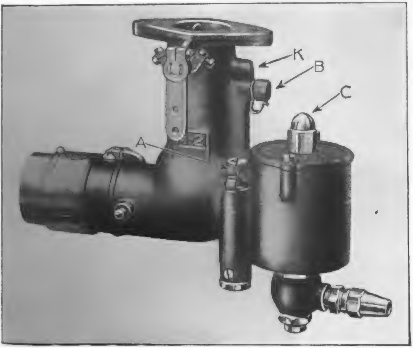


Fig. 95.—Exterior View of Stromberg Type M-2 Motor Truck Carburetor.

The gasoline for low speed is taken in above the throttle through a jet at K and is regulated by dilution with air as controlled by the low-speed adjusting screw B. Screwing B in, clockwise, gives more gasoline; outward, less. The best adjustment is usually one-half to three turns outward from a seating position. Note that this is only an idling adjustment and does not affect the mixture above eight miles per hour. When motor is idling properly there should be a steady hiss in the carburetor. If there is a weak cylinder or a manifold leak, or if the idle adjustment is very much too rich, the hiss will be unsteady.

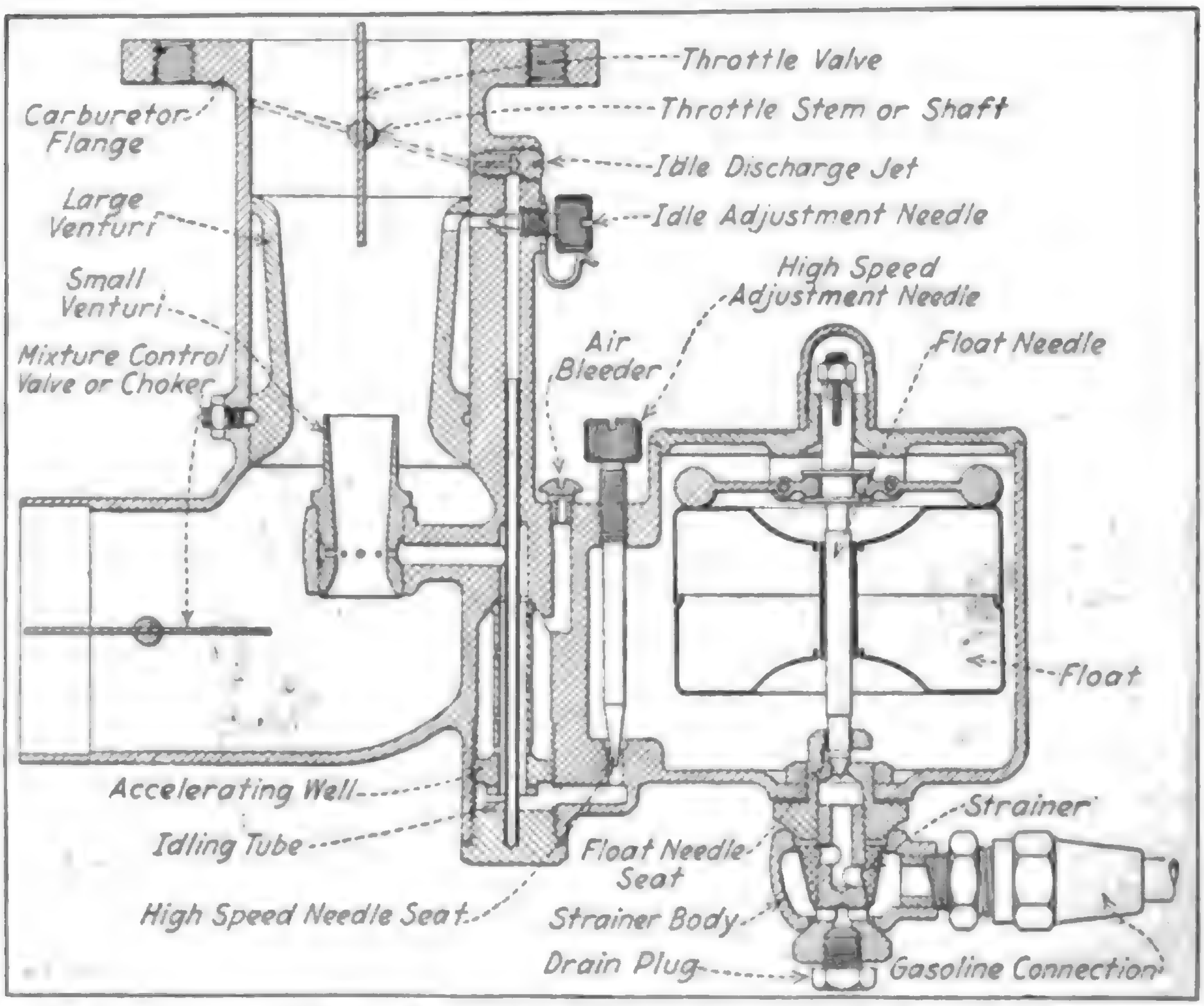

Throttle Valve
Throttle Stem or Shaft
Carburetor Flange
Idle Discharge Jet
Idle Adjustment Needle
Large Venturi
Small Venturi
High Speed Adjustment Needle
Air Bleeder
Float Needle
Mixture Control Valve or Choker
Float
Accelerating Well
Strainer
Idling Tube
Float Needle Seat
High Speed Needle Seat
Strainer Body
Drain Plug
Gasoline Connection

Fig. 96.—Sectional View Showing Construction of Stromberg Type M Plain Tube Carburetor.

For starting and warming up with the present-day fuel, it is absolutely necessary to use the dash or steering post control until proper operating temperature is attained. Ordinarily the motor will start readily with the control closed one-half to three-quarters of the way. In very cold weather it may be necessary to pull the control up all the way, but this should be done only for an instant, as this cuts off all the air and delivers raw gasoline only. In starting, the throttle should be nearly closed, or it may be opened and closed while the starter turns the motor over. Never keep the control fully up more than a moment at a time.

After starting the control should be drawn up as necessary and, allowing the motor a moment to steady itself, should be set at the point of best power, yet not too rich for smooth running; it should then be gradually lowered. While the motor is cold, care should be taken not to open the throttle so far that engine misfires, as this is a frequent cause of sooted spark plugs and gasoline or kerosene in the crankcase. For winter use, it is advisable to partly cover the radiator, as a water temperature of 130 degrees Fahrenheit or above is absolutely necessary if a motor is to show its normal flexibility and power. Under such conditions the full supply of hot air should, of course, be used. In the warm months the season adjustment shutter on the air horn may be opened to admit cold air.

If the motor, after steady running, suddenly ceases to perform properly, look after carburetor connections, etc., but do not start to change the adjustments until other causes of trouble have been investigated; these adjustments should only be changed with changes in fuel or changes in weather, and there are many other things on the motor subject to derangement besides the carburetor. If motor regularly refuses to start, see whether valve operated by choker closes securely; and always be sure that it is fully open, and dash control all the way down, for normal driving. To find whether gasoline is feeding to the carburetor, remove nut C and feel if needle inside is all the way down. If up, gasoline is not reaching the float chamber.

Rayfield Model O Carburetor.—The Rayfield carburetor is widely known as passenger car equipment, but the model O is entirely new. It is so designed that there are two levels of gasoline, and there are two nozzles. It is specified as a type having concentric float construction with a Venturi tube and air bled jet. The float mechanism is a fulcrum lever construction and is designed to have a positive method of controlling the flow of gasoline from the main supply line into the carburetor. The float chamber is directly below the mixing chamber, so that any gasoline accumulated by condensation may be returned from the manifold, flowing directly into the float chamber, thus obviating all leakage and flooding, as shown at Fig. 97A.

As stated, there are two gasoline levels, the fuel first entering a reservoir and then after rising to the top of a standpipe it flows into the float chamber, where it is controlled by the height of the float, the needle valve being opened and closed by the rise and fall of the float. There are two nozzles, the one for intermediate speed, which is supplied from the reservoir, while the other is supplied from the float chamber, this becoming operative at intermediate and high speeds. Acceleration is by means of an accelerating well, located in the reservoir, and when this well is drained air is bled through it into the fuel. Both the jets are constructed for the use of air bleeders; that is, air is bled in with the gasoline before it reaches the nozzle outlets.

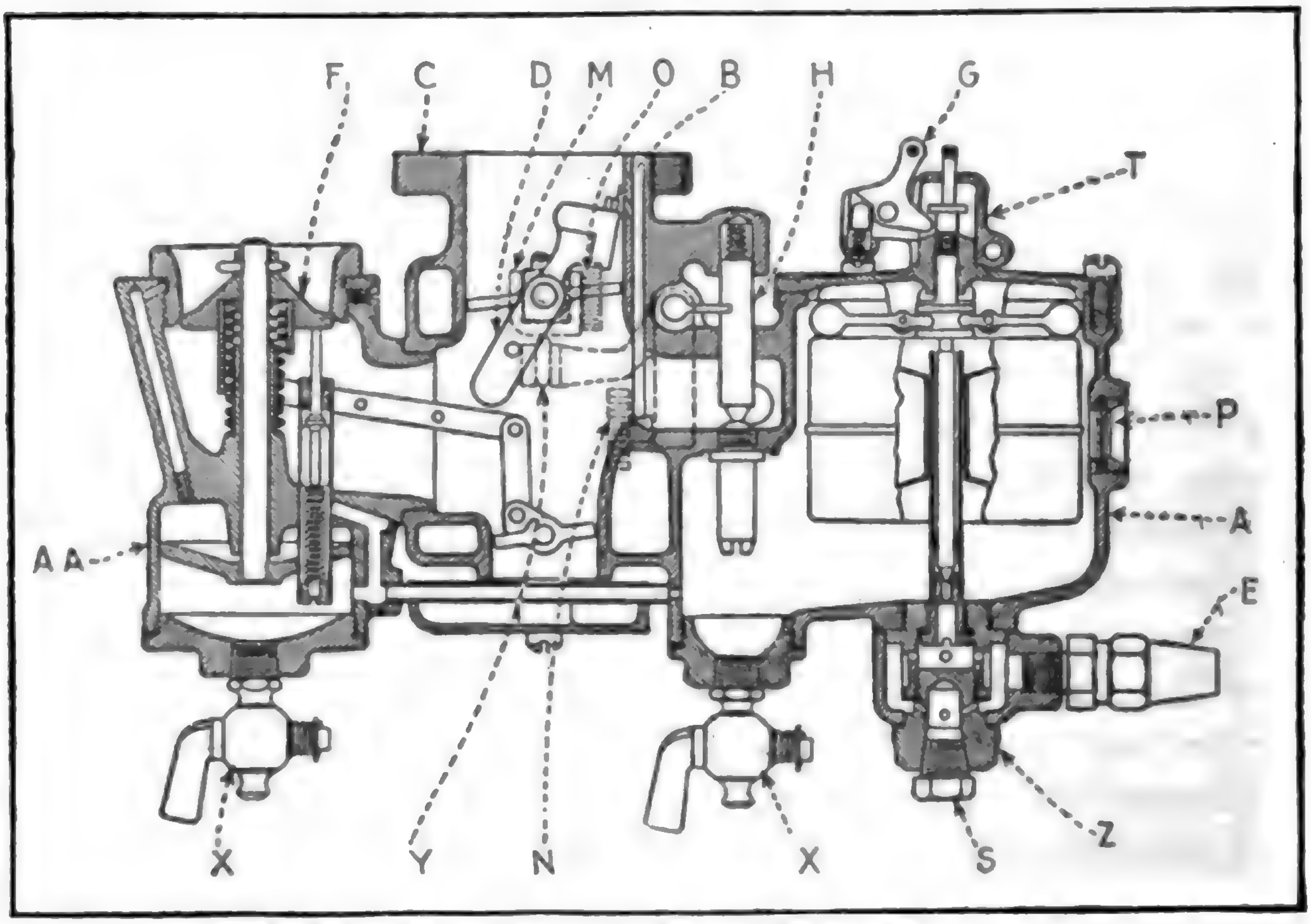


Fig. 97.—The Rayfield Mixed Type Carburetor.

Experience has proven that by the use of the two gasoline levels and two distinct and separate nozzles, it is possible to obtain a very thin intermediate mixture and at the same time to obtain sufficient fuel for high speed and heavy work whenever there is need. This construction is claimed to greatly economize fuel and to insure sufficient power for all work. There are two adjustments, the one being a low speed of idling adjustment, and the other is an intermediate or high speed adjustment. The idling gas passes through the throttle shaft when the nozzle is closed. When the throttle is opened it serves as a valve and releases this gas at intermediate or high speed, or when the throttle is at more than one-quarter opening.

An air valve choker is used for starting; that is, all air is cut off and a high velocity obtained at the nozzle. Both nozzles will supply ample fuel for this purpose. After the engine has been started the choke, of course, can be set about one-third closed. At this setting the engine will be quickly responsive, for the increased velocity resulting from the choking of the air valve will cause a heavy draft on the high speed nozzle, providing the fuel necessary for the short period the engine is heating. Because of the construction, hissing and other objectionable conditions during the period the engine is heating are obviated.

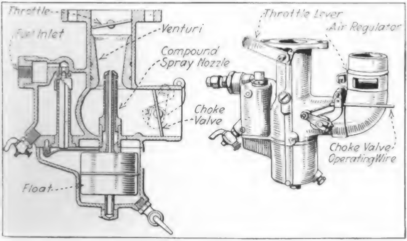


Fig. 97A.—The Rayfield Model O Carburetor.

Rayfield Mixed Type Carburetor.—This is not a new model, but there have been some detail refinements, designed to give quicker acceleration and take care of the lower grades of fuel. While the Model G is the prominent one of the line, there is a Model L which is the same in every respect, except that it is not water-jacketed as is the horizontal type of the Model L. The chief improvement lies in the rearrangement of the metering-pin, which is operated by the upper air valve. Previously this pin was held against the air valve by a spring, and the valve had to overcome the reaction of the spring to operate it. Now the metering-pin rides on the dashpot piston, which is on the lower end of the air valve stem, and moves upward and downward with the valve, but without any greater effort by the valve.

Rayfield uses a metering-pin, as shown at Fig. 97, which is lifted as the throttle opens in the main jet through a linkage, and so establishes a right to be classified as a metering-pin type, but it goes further. It incorporates an auxiliary nozzle, which also has a metering-pin which is depressed when the auxiliary air valve opens. Thus, by having two distinct nozzles, it establishes its right also to be classified as an expanding type of instrument. But Rayfield goes still further in that it combines a pumping action on the gasoline in the auxiliary nozzle whereby a very rich mixture is furnished for acceleration whenever the air valve is opened suddenly. This is accomplished by the piston on the lower end of the air valve stem, this piston working in a dashpot above the piston, and is admitted to the space below the piston by the disk valve in the piston. When the air valve suddenly opens, forcing the piston downward, this disk valve is closed automatically, forcing or pumping the gasoline upward through the fuel passage into the nozzle, where it is sprayed into the inrushing air. Only when the valve opens is this pumping function occurring. At other times the gasoline issues through the auxiliary nozzle, according to the suction of the motor. Thus Rayfield is a compound of two metering-pins in conjunction with the pumping function for acceleration. The dashpot also prevents any fluttering action of the valve, since the gasoline flow dampens sudden opening or closing.

Rayfield Adjustment for Various Speeds.—Adjusting for low speed. With throttle closed and dash control down, close nozzle needle H by turning low-speed adjustment N to the left until the block Y begins to leave cam M; then turn to the right about two complete turns. Open throttle not more than one-quarter by advancing lever marked G on steering wheel. Prime the carburetor by pulling steadily a few seconds on lever G (see cut of carburetor). Start motor and allow it to run until warm, then with retarded spark (see lever marked S on steering wheel), close throttle until motor runs slowly without stopping. Turn low speed adjustment N to the left until motor slows down, then to the right, a notch at a time, until the motor idles smoothly. If the motor does not throttle low enough, turn stop screw B to the left until the motor runs as slowly as desired. Adjusting high speed: With dash control down, advance the spark about one-quarter and open the throttle rather quickly. Should this cause the motor to backfire, the mixture is lean. Correct this by turning the high-speed adjustment O to the right, one notch at a time, until the throttle may be opened quickly without causing backfiring. If "loading" or "choking" is experienced when the motor is running under heavy load with throttle wide open, the mixture is too rich. This may be overcome by turning high-speed adjustment O to the left. Adjustments made for high speed will in no way affect low speed. Low-speed adjustment N must not be used to get a correct mixture at high speed. It is to be used only when motor is running idle.

Before attempting to start, when the motor is cold, open throttle not more than one-quarter, enrich the mixture by pulling up dash control full distance and prime carburetor by pulling lever G (see cut) a few seconds. To stop motor, pull up dash control, open throttle about one-quarter and switch off ignition. This leaves a rich mixture in the motor to insure easy starting. The dash control, when properly used, will facilitate starting, furnish a richer mixture when the motor is cold, and maintain a correct mixture under the most extreme atmospheric conditions. No changes should be made in carburetor adjustments, as the dash control will take care of cold weather as well as cold motor conditions. Raising dash control enriches the mixture by lifting nozzle needle, but ordinarily should be down for running. Do not change nozzles, nor alter the float chamber, as these are taken care of at the factory and are correct. The automatic air valve F should always be seated when motor is throttled down to its lower speed. The float chamber A and dash AA should be drained occasionally through drain cocks X to remove water and sediment which may have accumulated. To clean the trap at the bottom of the float chamber, remove nut Z. The parts may then be slipped apart and cleaned. When reassembling these parts be sure that the nut N is drawn up firmly to insure a tight joint. If it is desired merely to drain the trap, remove plug S. Never attempt to clean the carburetor while the motor is running.

Zenith Carburetor Construction.—The Zenith Model L, shown at Fig. 98, A, consists of a float chamber, a carbureting chamber, a system of nozzle and air passages, and a hot air sleeve and regulator. Gasoline from the tank enters the strainer body D (Fig. 98), passes through the filter screen D1, and enters the float chamber through the needle valve seat S, lifting the float F. As soon as the gasoline reaches a predetermined height in the float chamber, the metal float F, acting through the levers B and collar G2, closes the needle valve G1 on its seat S. From the float chamber to the motor, gasoline flows through three different channels, in various quantities and proportions, according to the size of nozzles, speed of the motor and to the size of the chokes.

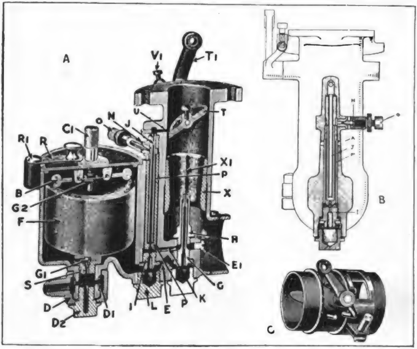


Fig. 98.—Sectional View of Zenith Carburetor Showing All Important Parts at A. B—View Showing Action of Load Speed Adjustment. C—Special Sleeve to Regulate Air Flow to Carburetor.

Idling Device.—At low speed, when the butterfly throttle valve T is nearly closed, the main jet and cap jet give but little or no gasoline, but, as there is considerable suction on the edge of the butterfly, the gasoline is drawn through the idling service. This device (see Figure 98, B), consists of the idling tube J within the secondary well P inserted in the first well, at the bottom of which the compensator I is located and which is open to the atmosphere through holes A.

Gasoline from the compensator I flows through the calibrated hole in the bottom of the secondary well P, which in turn is adjustably open to the air through the idling screw O and the idling seat N (see Figure 98, B). The idling tube I leads to a hole located at the edge of the butterfly throttle valve, where the suction is most strongly felt. This suction lifts the gasoline through the idling tube and, in combination with the air passing the butterfly valve, forms the idling mixture.

Air Sleeve.—The air sleeve (see Figure 98, C) is provided with an air strangler and temperature regulator. The two large rectangular holes can be closed entirely or partially by the brass band held together by a knurled headed screw. In the illustration the regulator is shown half open. The air strangler shutter is actuated by a lever, having a coiled spring to back it back to the open position. The air sleeve slips the primary air opening and is bored out at A to receive the flexible tubing. Flexible tubing should be attached to the air sleeve to supply the carburetor with air that has been heated by contact with the exhaust pipe. The air sleeve with strangler and temperature regulator is made in straight and angle forms. The throttle lever or levers can be furnished as desired from several standard designs. The idling adjusting screw can be assembled on either side of the carburetor barrel, providing there is no interference with the throttle lever movement.

Adjustments.—The choke X, main jet G, compensator I and idling tube J need not, as a rule, be disturbed. Their adjustment consists in finding, once for all, the different sizes or "setting" of air and gasoline passages suitable for the motor. These passages never vary and, once right, stay right. When the Zenith is furnished as standard equipment for a truck the setting is correct when the carburetor leaves the factory. The only adjustment that may be useful is the slow speed adjustment. The strength of the suction in the idling tube can be diminished by "turning out" screw O, thus admitting more air. "Turning in" the screw O increases the effect of the suction and causes the jet to flow more gasoline, making the mixture richer. It should be remembered that this adjustment varies the idling mixture only and has no effect upon the high speed action.

Open the throttle a little way in starting the engine. There will be a strong suction in the idling tube J, which will raise the gasoline contained in the well and thus prime the motor. In cold weather, use the strangler opening throttle a little more, and allow the motor to run a few minutes before starting the car. It is better to drive the car for a time with strangler partly closed—until motor is well warmed. In running after the engine becomes properly heated the air strangler should be open.

Care of the Carburetor.—In a new car it may happen that the gasoline line or the tank will give off scale, the result of oxidation. These impurities may clog the filter and cause the motor to miss and pop. Dirt and water also cause trouble. Clean the pipe and carburetor thoroughly. The carburetor may be taken apart for cleaning and put together again without fear of disturbing the adjustment. If cleaning is necessary, be sure to have the float cover well seated, the needle valve seat and the various jets screwed down tight, and the butterfly throttle fastened properly on the shaft, so that it may open fully. When closed the lower edge of the butterfly throttle should cover the idling hole. To see if there is any gasoline in the carburetor, remove needle valve cap C1; if needle valve can be depressed with the finger, there is no gasoline in the carburetor.

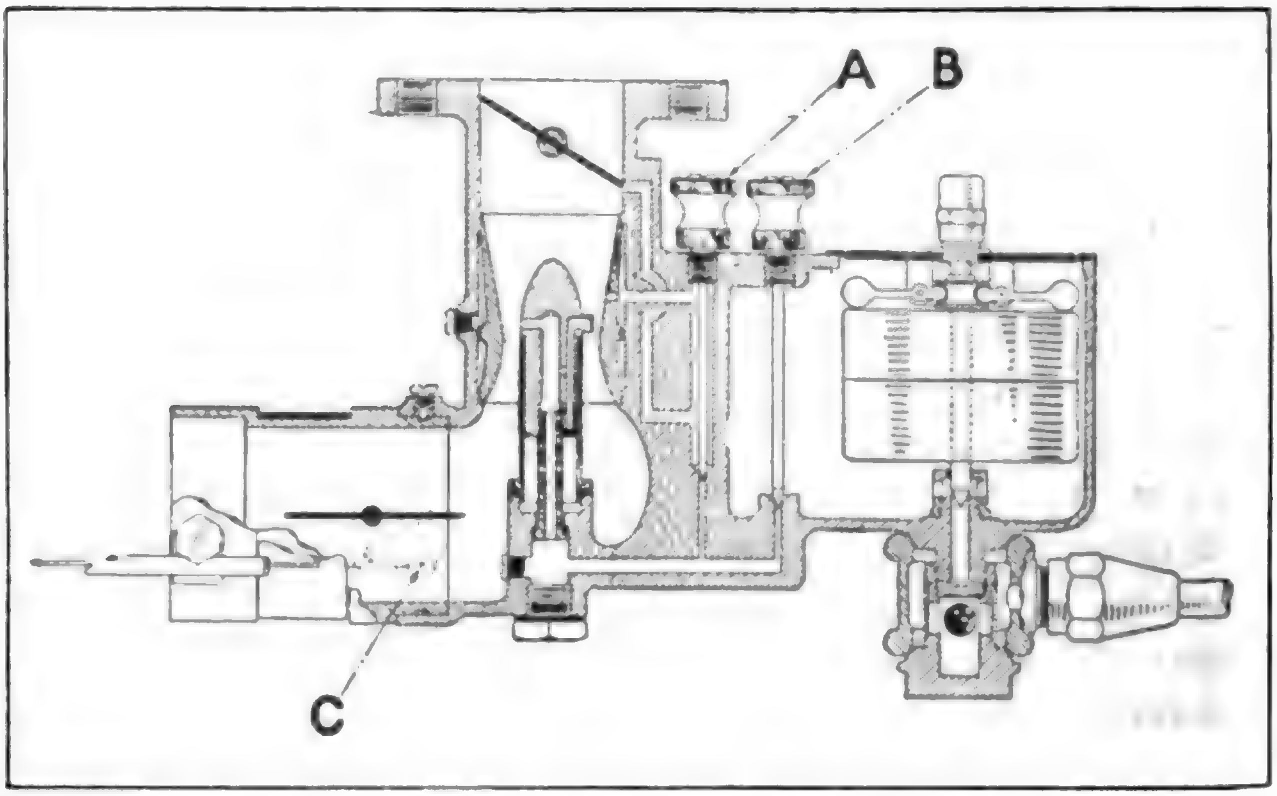


Fig. 99.—Sectional View of Schebler Motor Truck Carburetor.

Ordering Chokes and Jets.—The chokes are numbered in millimeters according to the size of their smallest inside diameter. The jets and compensators are numbered in hundredths of a millimeter. A one-hundred jet has one millimeter hole and is smaller than a one-hundred-five jet. They are graded by five-hundredths of a millimeter apart. Size numbers are found on each part.

Schebler Model A, Plain Tube Carburetor.—This plain tube carburetor, shown at Fig. 99, is built around the "Pitot" tube principle, utilizing the differential head created by an up-stream and down-stream "Pitot" to control the fuel delivery. The use of the pitot tube principle gives a fuel flow absolutely proportioned and controlled by the air, for acceleration. The Model A carburetor has a low speed or idle service, which delivers fuel and air at the low edge of the throttle disc in its closed position. This idle is so designed that it operates and blends with the fuel supply from the main nozzle in such a manner as to prevent any flat or dead spots. This carburetor has no small air vents open to the outside air to clog up with dust or foreign substance. In case of a backfire there is no chance of back-pressure gas blowing through to the outside of the carburetor and causing a fire.

It has two gasoline needle adjustments: one for adjusting the idle, and one for the high speed. These two adjustments take care of the slight variations that occur in all motors, and also the extreme changes in weather conditions. The Model A carburetor is equipped with a starting shutter in the air intake, and gasoline strainer at the bottom of the bowl. The gasoline connection and flange are made in accordance with the S.A.E. Standard.

Before adjusting the carburetor, be sure that the fuel tank and all pipe connections are clean; see that the ignition is properly timed; that all connections between the intake valve of the motor and the carburetor are tight and that there are no air leaks of any kind. See that the choker C in the air intake is connected for initial starting, so that when the choker on the dash is pulled out, all the air will be shut off. After the car has been started, this choker should be turned to its original position as the motor warms up. Open both gasoline needles A and B about three or four complete turns from the closed position. Open throttle about one-eighth and start motor. Let the motor warm up thoroughly before making adjustments on the carburetor. After the motor has been thoroughly warmed, then adjust idle needle A until the correct mixture is obtained for idle running. Next open the throttle about one-quarter way and adjust gasoline needle B.

Holley Model K Carburetor.—The 1¼-inch Holley Model K carburetor used on International Harvester truck models

F, H and K is shown at Fig. 100. The gasoline comes from the tank through the copper tube stopcock and strainer and up to the float valve. The float holds the gasoline level from one-sixteenth inch to one-eighth inch below the top of the spray nozzle basin inside the air passage. This level can be seen by removing the top section of the carburetor. Into this spool the spray nozzle and the law-speed tube dip. The rate at which fuel flows from the float chamber into this spool is regulated by the needle valve as shown in inset A, Fig. 100. It is evident that the depth of the pool will vary with the rate at which gasoline is being used, and this variation, together with the shape and arrangement of the Venturi tubes, gives the necessary cor-

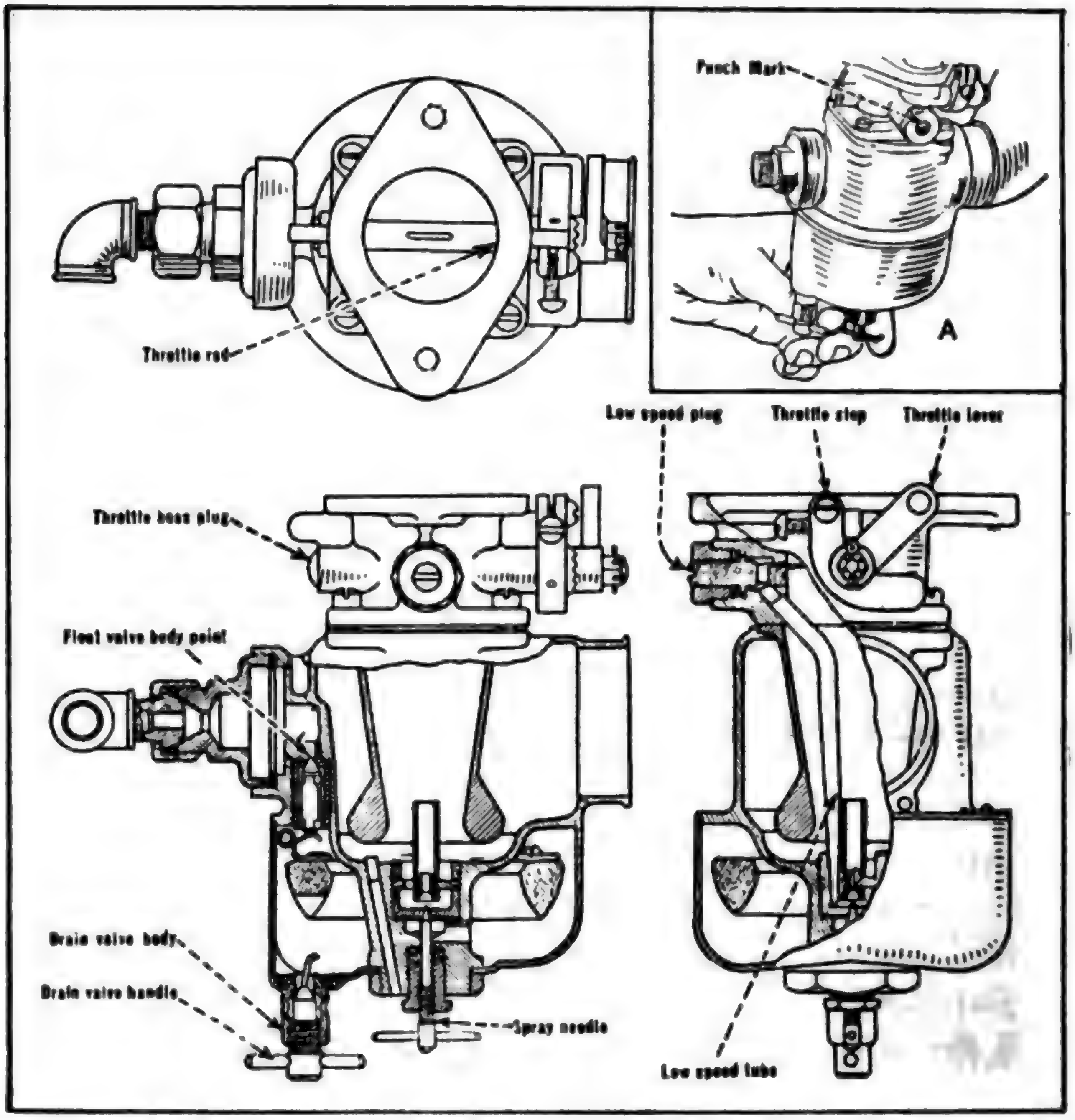

Punch Mark
Throttle rod
A
Low speed plug
Throttle stop
Throttle lever
Throttle boss plug
Float valve body point
Drain valve body
Drain valve handle
Spray needle
Low speed tube

Fig. 100.—Sectional Views Showing Construction of Special Holley Carburetor Used on the International Harvester Motor Trucks.

rection for speed and load and makes an auxiliary air valve unnecessary.

Holley Carburetor Adjustment.—The idling tube connects at its upper end with plug, having a hole drilled off center leading into the air passage. A screwdriver slot in the outer end of this plug allows of turning it, after locknut has been loosened. A prick punch mark on the outer end of the plug shows the location of the hole. It is evident that if the hole is brought entirely above the closed throttle, the suction will be very strong and a large amount of gasoline be drawn through the hole. If the hole is entirely below the throttle the resulting mixture will be very weak. The proper adjustment lies between the two extremes.

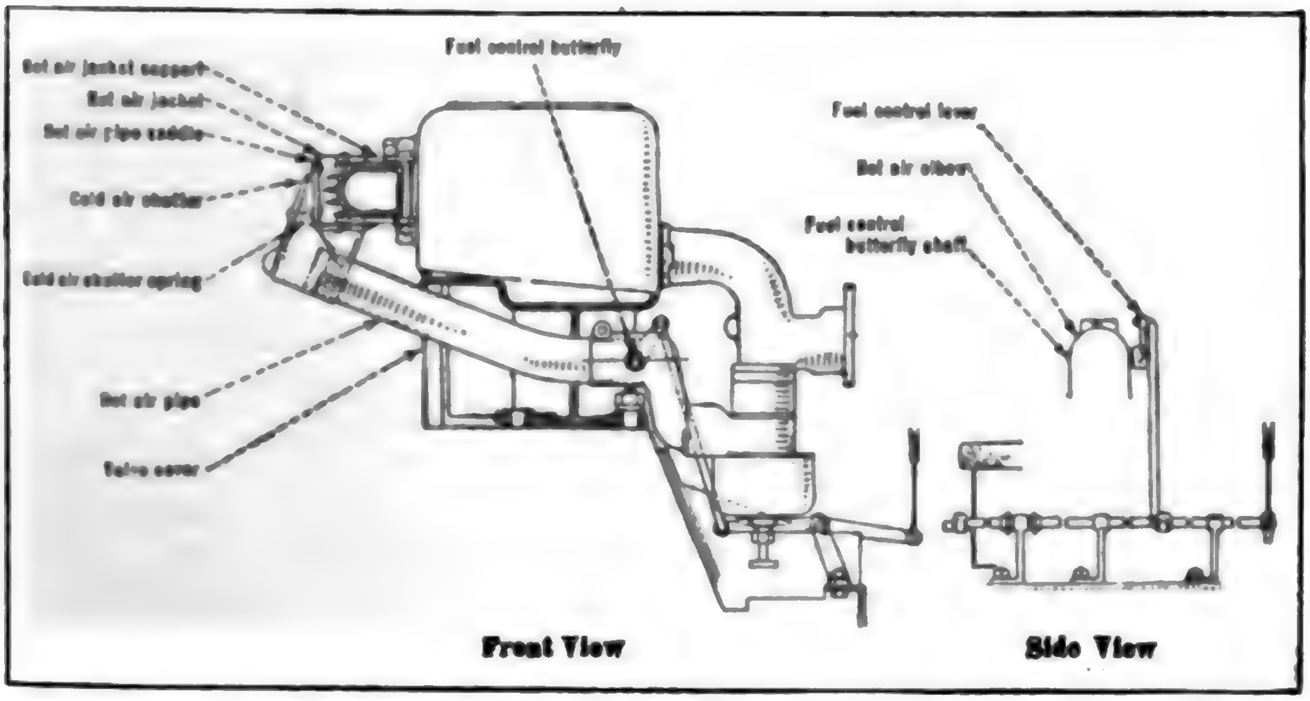

Hot air jacket support
Hot air jacket
Hot air pipe saddle
Cold air shutter
Cold air shutter spring
Hot air pipe
Valve cover
Fuel control butterfly
Fuel control lever
Hot air elbow
Fuel control butterfly shaft
Front View
Side View

Fig. 101.—Diagram Showing Method of Obtaining Hot Air from the Exhaust Manifold and to Supply Cooled Air When Required in International Harvester Truck Fuel System.

The adjustment of throttle stopscrew will also affect the mixture as well as idling speed, as the edge of the throttle rises quite rapidly as it approaches the closed position. The two should be adjusted together so that the engine idles steadily at the speed desired. The idling adjustment has no effect on the running adjustment, except when throttle is nearly closed. The only running adjustment is that of the needle valve. This may be opened 1¼ turns as a trial position, but better economy will be secured in warm weather with less opening and more may be needed in cold. (See illustration, Fig. 100, A.)

Adjust the carburetor when the motor is warm. In cold

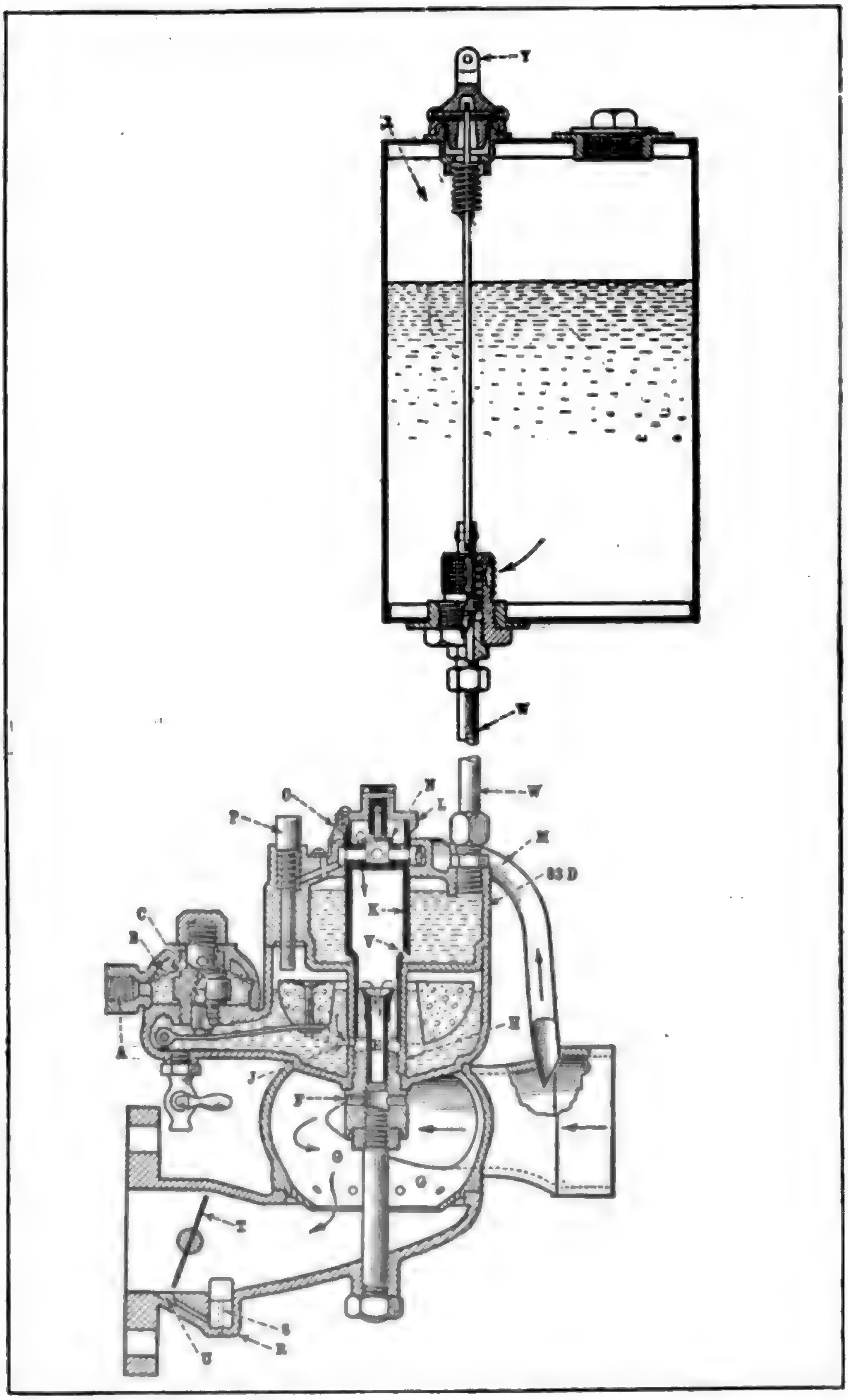


Fig. 102.—Sectional View of the International Harvester Ensign Carburetor Which Uses Low Grade Fuel.

weather, stop the motor for the night or a long stop by flooding the carburetor; to do this, pull up on fuel control wire button. This will fill the cylinders with a mixture too rich to explode, but it will be all right when the motor gets cold.

Ensign Carburetor.—The Ensign 1¼-inch carburetor is used on International Harvester Model G two-ton trucks and is shown at Fig. 102, type JG being employed for gasoline and JD for the territory west of the Rocky Mountains, where distillate is the common fuel. The following description applies to both: The fuel enters at A, passes upward through screen B, and downward through the float-controlled needle valve, C, into the float chamber, D. The float maintains the fuel level 1/32 inch below the top of suction tube E, which opens through holes F at its lower end into the centrifugal chamber, G. Tube E is surrounded by a larger tube, H, into which fuel enters through small hole, J. The effective opening of this hole is controlled by gas-adjusting tube, K, shown in solid black, which can be screwed up and down by its knurled head. This tube performs the function of the usual gas-adjusting needle valve. A compensating air tube, M, is connected to the interior of the gas-adjusting tube K, through the automatic valve N, which lifts when the air speed through the carburetor becomes high enough, and lowers the vacuum in the gas-adjusting tube, preventing the formation of too rich a mixture.

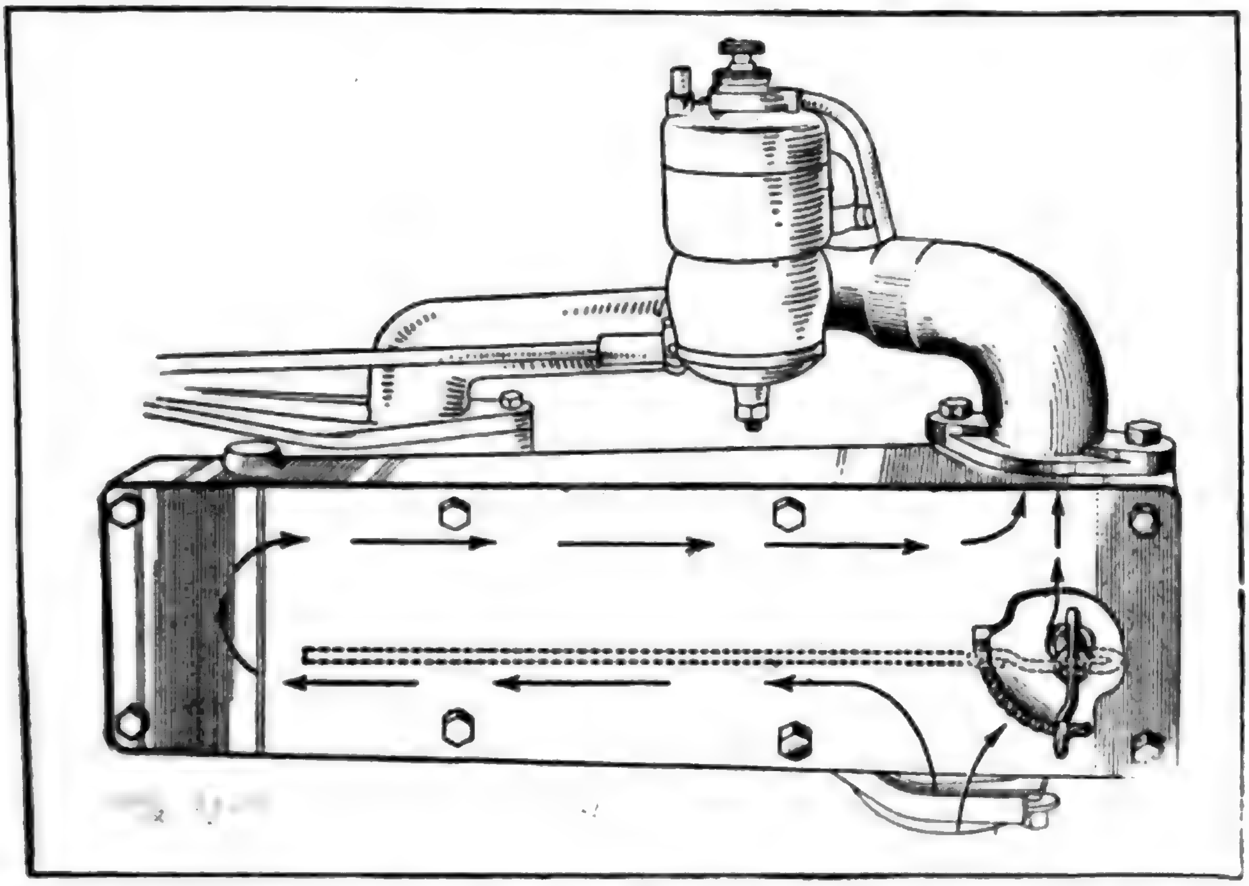


Fig. 103.—Special Exhaust Control Used with International Harvester Ensign Carburetor to Heat the Vaporizing Device.

Type JD carburetor, shown in illustration Fig. 102, is equipped with a priming bowl in the float cover and a priming tank X for gasoline is located on the dash beside the vacuum tank, and connected by tube to the priming bowl at W.

To start a cold distillate burning motor, tip priming lever Y on top of priming tank in any direction. This lifts the valve in bottom of tank and gasoline flows into the priming bowl. The amount required will depend upon the temperature of the motor. The gasoline will flow through hole V and down into the idling well S. Set the throttle a little more open than idling position and crank motor. If one priming does not warm the motor up enough to run properly on distillate, give it a little more gasoline, but be careful not to overprime. To correct overpriming, open throttle wide and crank slowly, closing throttle when motor comes to speed.

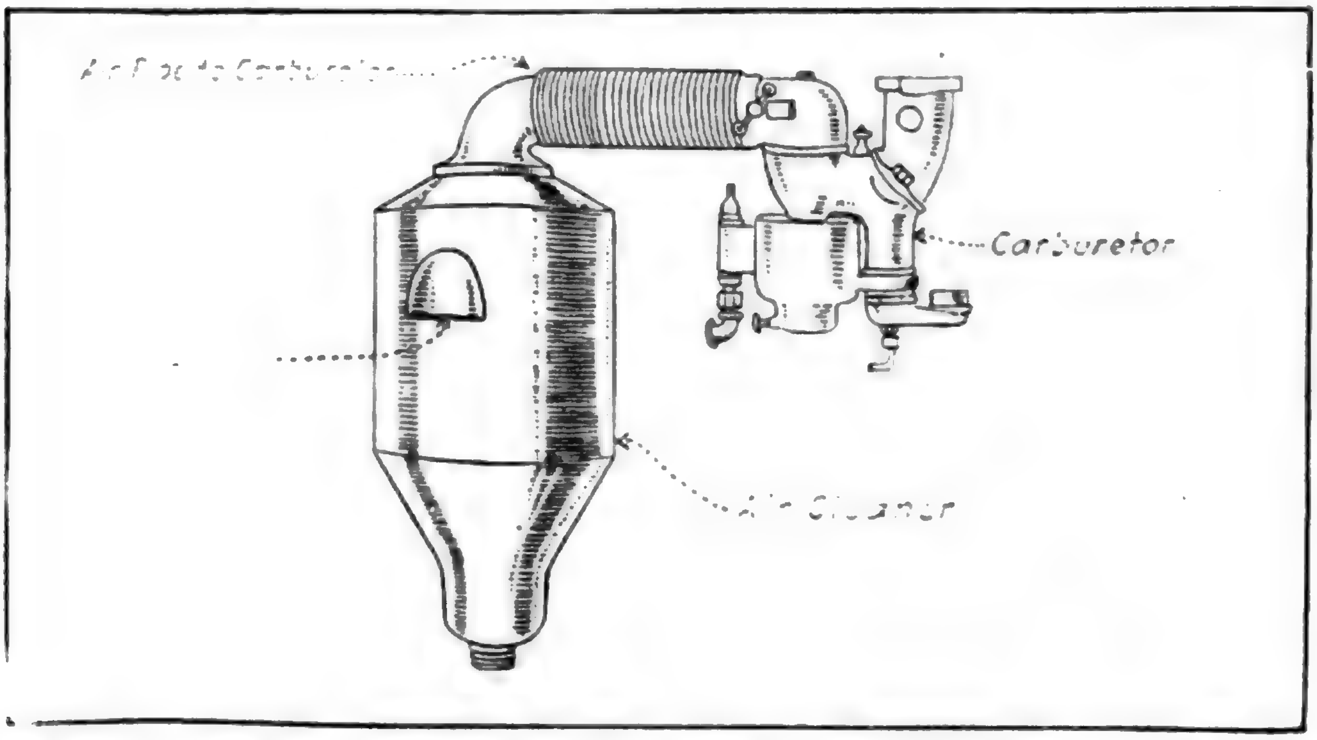


Fig. 104.—The Bennett Air Cleaner Which Removes Dust and Other Solid Matter from the Incoming Air.

Cold Weather Starting.—Gasoline vaporizes slowly when cold and at very low temperature will not form an ignitable mixture. In such cases, prime the motor with warmed gasoline or use special high test gasoline or a mixture of one part ether to seven parts gasoline for priming. If you warm the gasoline, don't take it to a fire but set a small can of it in a pan of hot water. Warming the intake pipe by wrapping in cloths wet with hot water will generally enable you to start in the coldest weather. Priming can be carried too far; filling the cylinder with a mixture too rich to ignite, but this is not likely in very cold weather. In such a case open throttle wide and crank slowly until a correct mixture is formed in the cylinders, when the motor will begin firing.

A hot air jacket, as shown at Fig. 103, is provided around the exhaust manifold with a bypass valve adjustable by a wire lever. When the lever is horizontal the air is hottest. Set to suit weather conditions, as too much hot air cuts down power; too little cuts down power and economy and the engine does not handle well.

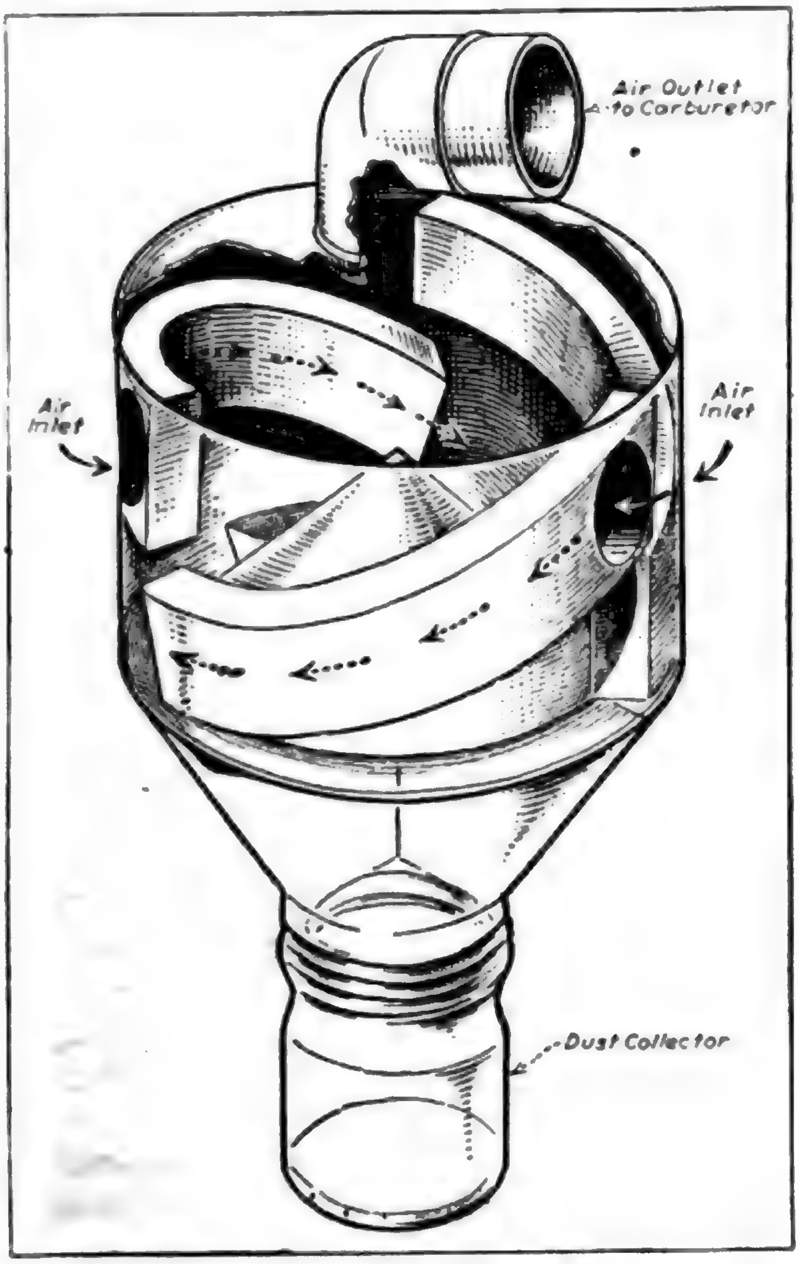


Fig. 105.—Interior of Special Air Cleaner Operating on the Centrifugal Principle.

Air Cleaner.—Considerable trouble is caused by road and field dust getting into the engine through the air intake, especially on tractors and trucks used in construction work as excavating or around a stone crusher. The object of the Bennett air cleaner, shown at Fig. 104, is to filter all air and remove dust and other foreign matter it holds in suspension. Much of this matter is of an abrasive nature and has a deteriorating effect on the bearing surfaces, and all of it is thickening and reducing the efficiency of the lubricating oil. It is said that there are no moving parts and no cloths to clean, no screens to clog or adjustments needed. A cap is removed to empty out dust, otherwise the cleaner requires no attention. It is made in various sizes to fit all standard carburetors and will function properly with any power plant.

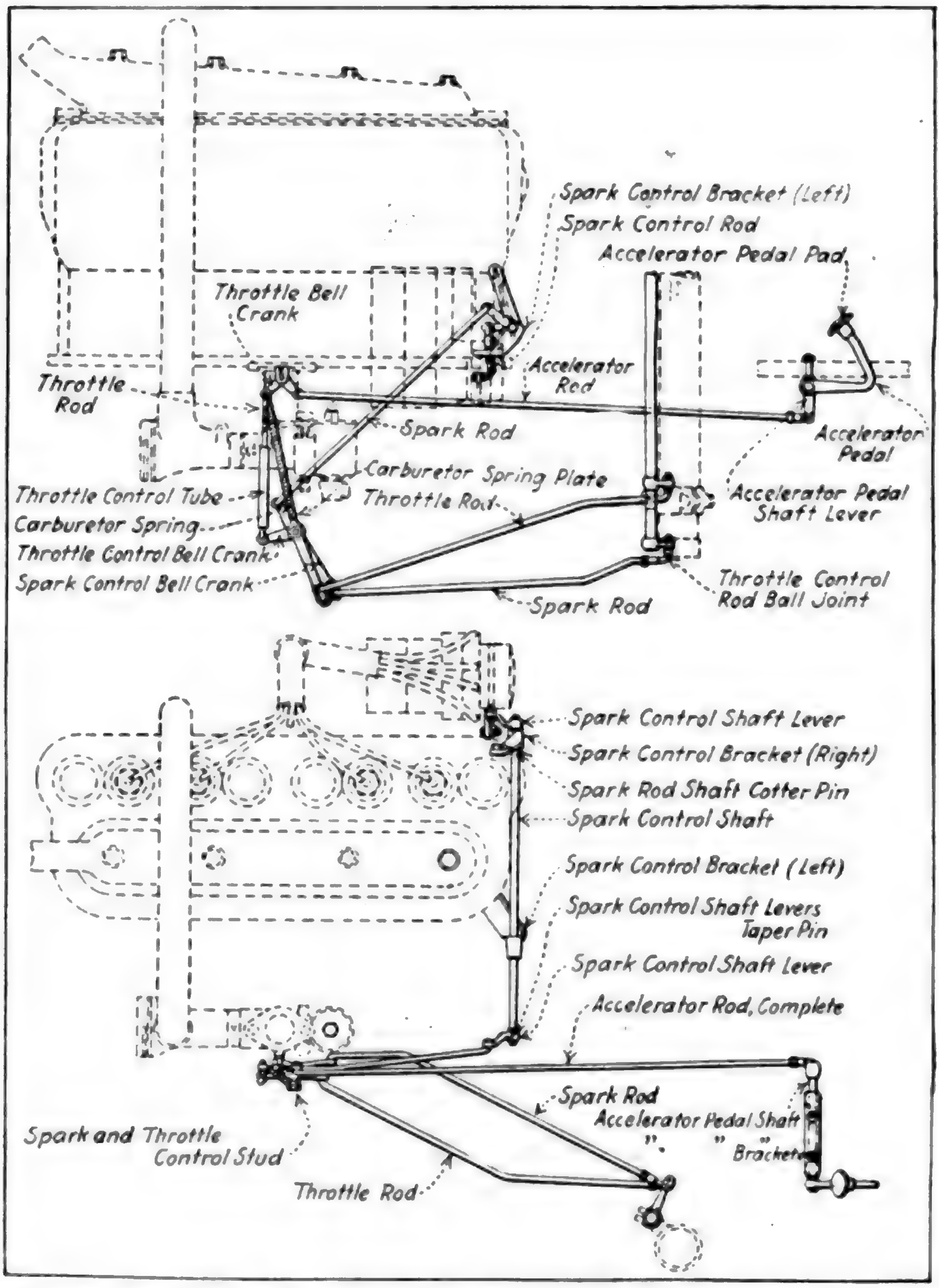

Spark Control Bracket (Left)
Spark Control Rod
Accelerator Pedal Pad
Throttle Bell Crank
Throttle Rod
Accelerator Rod
Spark Rod
Accelerator Pedal
Carburetor Spring Plate
Throttle Rod
Accelerator Pedal Shaft Lever
Throttle Control Tube
Carburetor Spring
Throttle Control Bell Crank
Spark Control Bell Crank
Spark Rod
Throttle Control Rod Ball Joint
Spark Control Shaft Lever
Spark Control Bracket (Right)
Spark Rod Shaft Cotter Pin
Spark Control Shaft
Spark Control Bracket (Left)
Spark Control Shaft Levers Taper Pin
Spark Control Shaft Lever
Accelerator Rod, Complete
Spark Rod
Accelerator Pedal Shaft
" " Bracket
Spark and Throttle Control Stud
Throttle Rod

Fig. 106.—Side and Plan Views of Typical Motor Truck Power Plant Showing Spark and Throttle Control Levers and Linkage.

The air is drawn by motor suction through three openings in the side of the cleaner into helical tubes. These tubes cause the air to swirl around in the cleaner, and as the tubes have a downward slant, the centrifugal action, together with gravity, separates the dust from the air and causes it to collect in the glass jar which is screwed to the lower end of the sheet-metal housing, as shown at Fig. 105. The clean air passes up out of the top of the housing to the carburetor. The use of such an air cleaner is claimed to result in less wear on engine bearings, piston rings and valves; increased lubricating oil economy, better fuel economy, less carbon trouble and longer life of the carburetor. The cleaner may be connected to the carburetor by means of a short length of flexible tube. Other makes of cleaners filter the air through cloth or wire gauze screens or wash it by passing it through water.

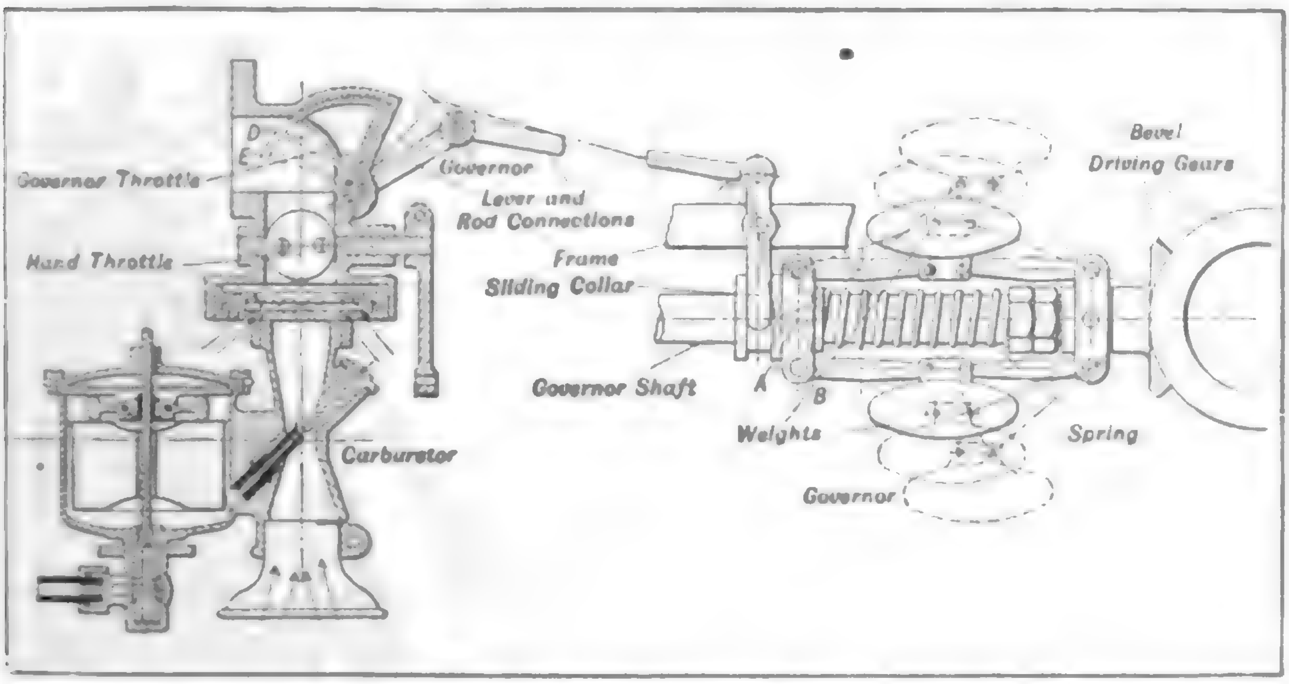


Fig. 107.—Showing Method of Regulating Fuel Mixture Supplied to the Cylinders by Means of a Centrifugal Governor Which Automatically Reduces the Quantity When the Engine Speed Exceeds a Certain Predetermined Limit.

Methods of Gas-Supply Regulation.—The methods of regulating the amount of gas supplied the cylinder vary to some extent, though the general system is to introduce some form of butterfly or shutter valve in the mixture pipe between the mixing chamber and the valve chamber. These valves are operated by rod connections to hand lever placed in top of the steering post or accelerator pedal on foot boards, as shown at Fig. 106, and the amount of gas passing from the carburetor into the cylinder depends upon the amount of opening provided by the valve. When it is fully opened the gas may fill the cylinders easily, though as its position changes the area of the mixture passage is gradually decreased and the amount of gas passing through reduced.

In some cases the hand throttle is supplemented by an automatic governor which is designed to shut off the gas supply should the engine speed increase beyond a certain predetermined point. A carburetor fitted with both hand-operated throttle and shutter actuated by a governor from the engine is shown at Fig. 107. The hand throttle is a simple disc valve attached to a stem passing through the mixture pipe at a central point. When in the position shown the passage is fully opened. The governor throttle is a shutter valve placed in a special pocket above the

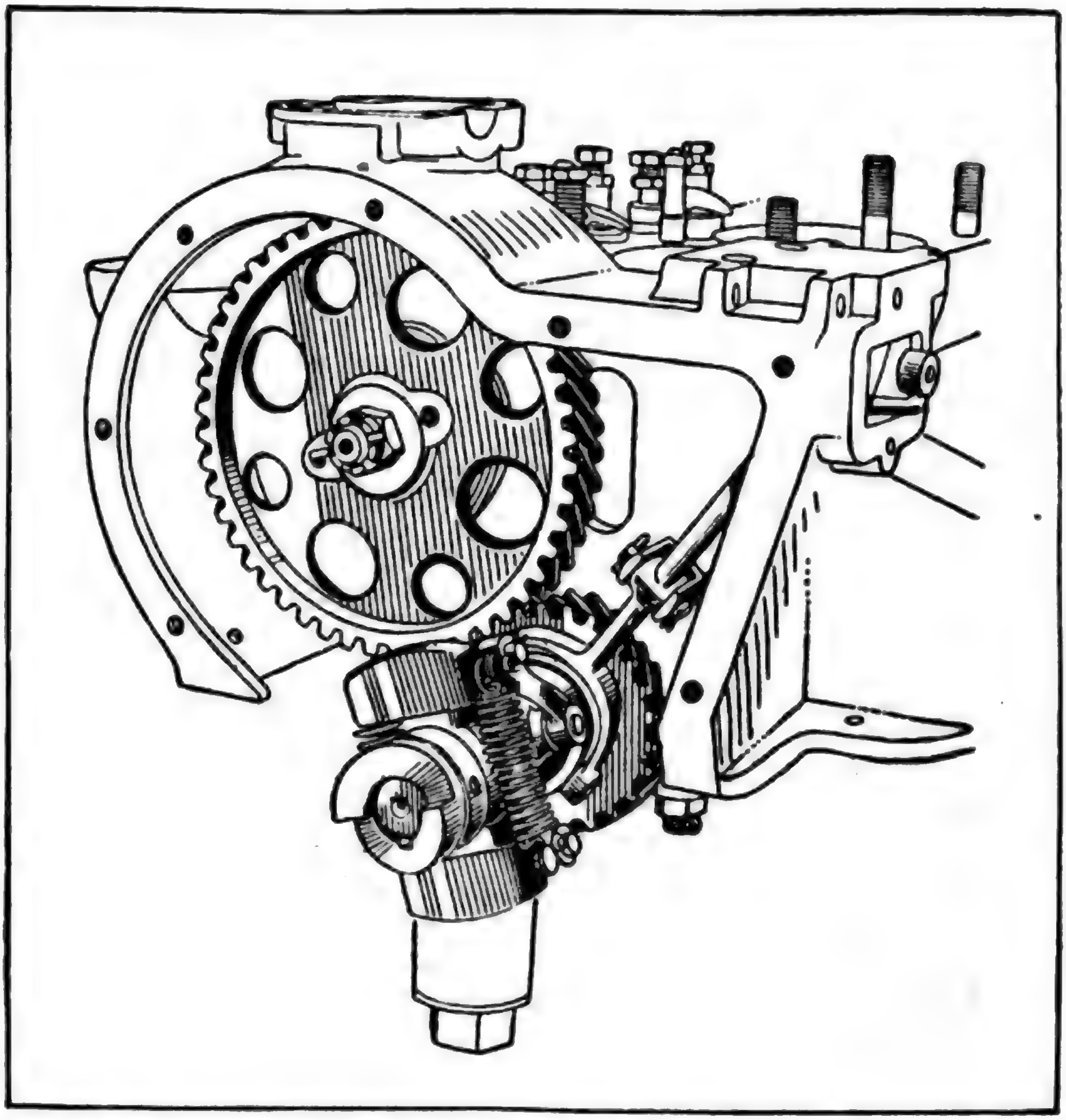


Fig. 108.—Showing How Governor of the International Harvester Motor Truck is Mounted on the Front End of the Crankshaft.

hand-operated disc. It is worked by lever and rod connection by a centrifugal governor.

The governor consists of two weights pivoted in such a manner that they lie close to the governor shaft when engine speeds are low. As the speed of the governor shaft increases, the weights tend to fly out from center due to centrifugal force, and as they are thrown out they pull a sliding collar back against

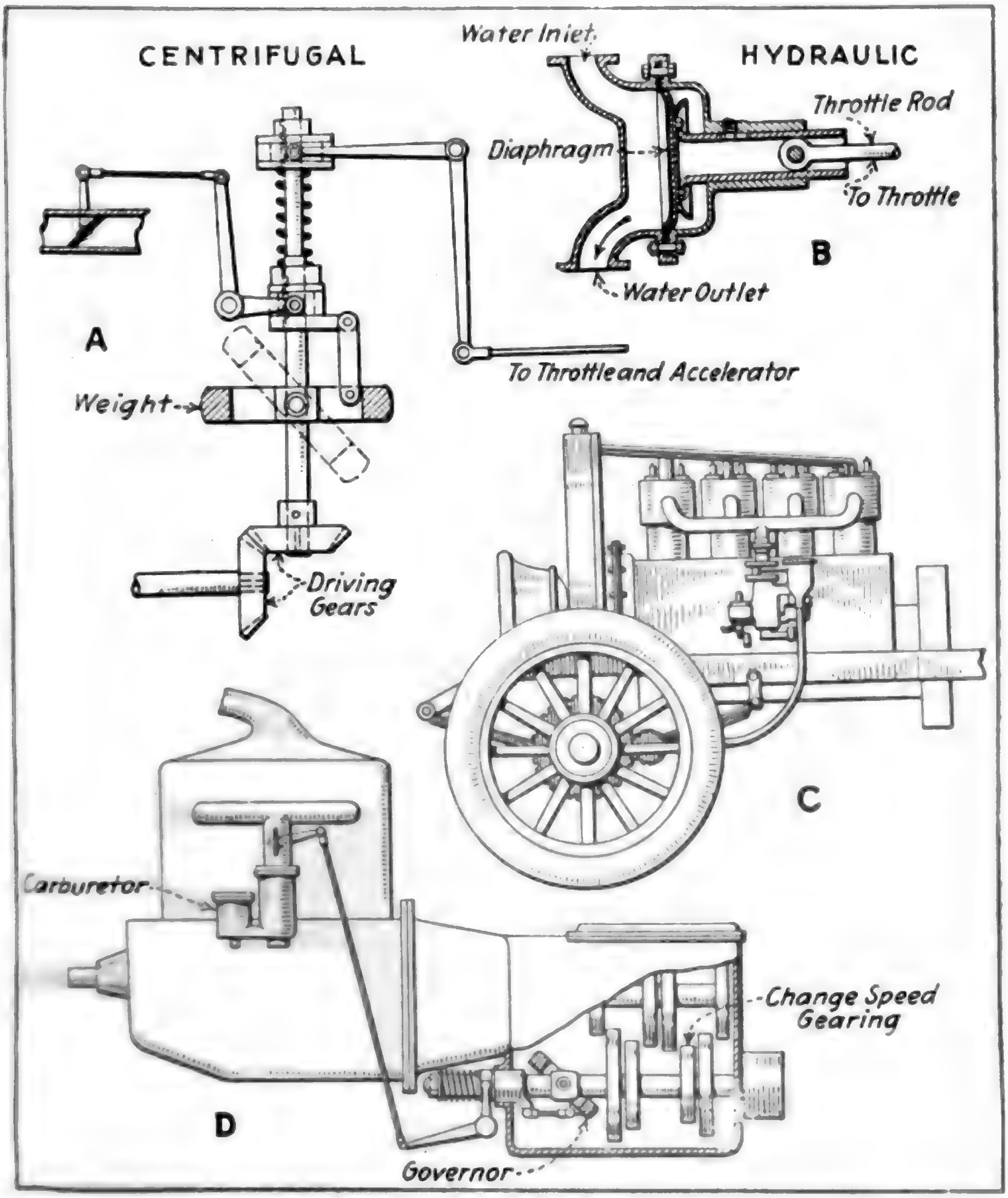

CENTRIFUGAL
Water Inlet
HYDRAULIC
Throttle Rod
Diaphragm
To Throttle
B
Water Outlet
A
To Throttle and Accelerator
Weight
Driving Gears
C
Carburetor
Change Speed Gearing
D
Governor

Fig. 109.—Diagram Showing Various Forms of Mixture Supply Governors. A—Throttle Control by Movable Weight. B—Hydraulic Regulator. C—Governor Actuated by Flexible Shaft Drive from the Front Wheels. D—Governor Weight Mounted on Lay Shaft of Change Speed Gearing.

a spring. The sliding collar actuates a lever which closes the governor-throttle valve by the rod connecting it to the governor. The governor is driven from the engine by some form of driving gear, or it may be located on the camshaft. The amount of weights fly out as regulated by the spring, and as its tension is increased it will take a higher engine speed to throw the weights out sufficiently to close the governor throttle. When the spring is weakened the governor weights fly out at lower speeds and the governor throttle is closed sooner.

Such a device is useful in preventing racing of the engine under certain conditions. For instance, if the car was climbing a hill on one of the lower gear ratios which would permit the engine to run quite fast and the clutch pedal was depressed so that the drive would be momentarily interrupted, the tendency of the engine, thus relieved of its load, would be run at an extremely high rate of speed. If the operator was fully occupied in steering and shifting gears he could not regulate the hand-throttle valve and the result would be that the engine would run dangerously fast. When a governor is fitted, as soon as the engine speed tends to become excessive the weights fly out and the supply of gas is diminished automatically.

A governor is also useful on commercial cars where it is desired to keep the vehicle speed within certain limits. As speed is directly dependent upon the number of engine revolutions, the governor can be set in such a way that the engine will run up to a certain point and no faster. Governors are not so widely used at the present time as they were in the past, owing to improvements in carburetor control devices. All governors do not operate on the centrifugal principle. Some are hydraulic, others are worked by compressed air. The fly ball governor described is the most common, and it shows clearly the principle of action and utility of such devices. Governors are sometimes operated by a flexible shaft from a road wheel. A compact form of governor of this type, used on the International Harvester trucks, is shown at Fig. 108. The operation can be readily ascertained by study of the simple form at Fig. 109, A.

Hydraulic Governor.—A hydraulic governor is used in some models of the Packard truck, this consisting of a chamber carrying a diaphragm against which the stream of cooling water from the circulating pump of the cooling system impinges. When the speed of the engine becomes too great the flow of cooling water is more rapid and the pressure against the diaphragm will operate linkage to close the throttle and slow down the engine. The principle involved is clearly shown at Fig. 109, B. The governor is not always driven from the engine. At C, it is operated from the front wheel; at D, it is incorporated in the gearset. Both of these are unusual applications.

Kramer Governor.—Controlling the speed of the motor by utilizing the velocity of the inrushing gases is the feature of a new governor known as the Kramer. As is shown in Fig. 110, as the speed of the motor grows higher, the increasing velocity of the gases past the floating disc in the intake passage raises this disc and closes the damper, placed below it. Thus when the speed of the gases reaches a predetermined amount the butterfly begins to close and the speed drops. These two members are contained in a suitable casing which is inserted between the carburetor and intake manifold. Since it is compact and self-contained, it may be easily attached to any motor. There are no revolving parts and little to get out of order or wear. It is stated that all governors are thoroughly tested and set for a maximum speed of about 1,000 revolutions per minute. The governor may be simply adjusted to any speed desired. This gives a direct control of the piston speed of the motor as the speed of the intake gases is a direct function of the piston speed. This is, of course, within the limits of ordinary running, where the volumetric efficiency of the motor does not vary sufficiently to alter the proportions to an appreciable extent. Ball bearings of

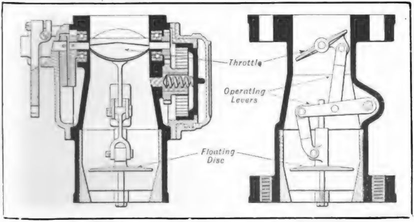


Fig. 110.—The Kramer Automatic Governor.

the single row type are used on the shaft of the butterfly and a clock spring regulates its action. The throttle shaft is ground true to 1-1000 inch. Hardened steel bushings are used in the links.

Pierce Governor.—The governor is mounted between the carburetor and intake manifold, and is driven by means of a flexible shaft, encased in an oil-tight flexible tube, to the governor bevel drive gear at rear end of exhaust camshaft or other suitable driving connection on the engine.

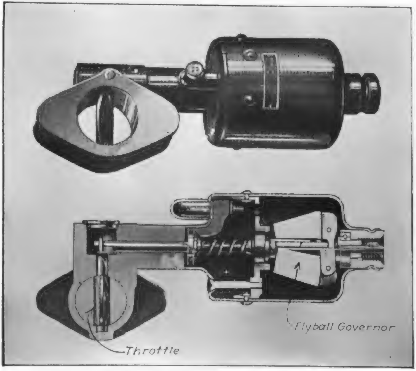


Fig. 111.—Views Showing Construction of the Pierce Automatic Governor.

The butterfly valve, in the governor valve box, as shown at Fig. 111, is normally in a position that does not obstruct the flow of mixture from the carburetor to the manifold, but as the engine speed increases, the valve area is reduced until the maximum speed of 1,350 r.p.m. is attained, when the valve is closed entirely. The valve is actuated by what is known as the flyball principle, operating as follows: two weights are so pivoted on the controller shaft that they swing outward, as the speed of the shaft increases, forcing a plunger forward which in turn operates the butterfly valve. The plunger is forced against a spring calibrated to a standard pressure, so that the weights are returned to their normal position as the speed of the shaft decreases. A paper gasket seals the joints on each side of governor box, preventing leakage of air into the manifold. The governor is adjusted at the factory, and the adjustment sealed. This seal must not be broken unless absolutely necessary to change the adjustment, which is as follows: Cut the seal wire, pull off cap and turn screw to the right or clockwise to decrease the engine speed, and to the left or anti-clockwise increases the engine speed. When proper adjustment has been made, replace cap and seal same, so adjustment cannot be tampered with, or affected by vibration. The governor connections at each end of the flexible shaft should be examined frequently to insure alignment of gears at lower end and shaft at governor end. It is especially valuable for use with engines not originally designed with a governor incorporated in the motor mechanism.

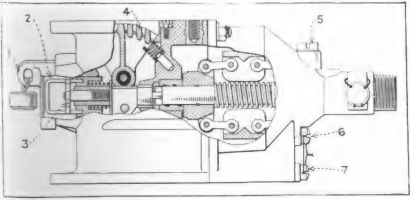


Fig. 112.—Cutaway View Showing Construction of the Simplex Governor.

Simplex Governor.—Briefly, the governor, outlined at Fig. 112, consists of a grid valve controlled by the action of four balls or weights. The weights are mounted about a movable shaft which operates through a sleeve. Centrifugal force which results from the whirling of the balls around the shaft causes them to pull away. This action forces the shaft through the sleeve and against the grid valve, cutting down the supply of fuel. As these weights are raised and lowered by the engine, they regulate the flow of gas according to the needs of the moment. When the engine is turning over 1,191 revolutions the governor automatically cuts off all the fuel, thus restricting the engine and consequently the vehicle speed. The same general pattern is also made in the "Duplex" form, one grid valve being actuated by mechanism connected to the engine as in the "Simplex," the other being operated by flexible shaft connection with one of the front wheels or from some members of the transmission system. In this way a double check is obtained on the motor speed.

Care of Simplex Governor.—To lubricate, remove the oil-filler screw (5) and fill chamber weekly. Use medium cylinder oil, and in winter add to it an equal amount of light machine oil. Every 1,000 miles remove screw (6), shown in Fig. 112, fill half full of machine oil, run for ten minutes to clean interior and drain. Refill the chamber with cylinder oil as above described. Be sure that the governor does not run without oil, as it might injure its bearings. Keep screws 7 and 6 with copper washers tight to prevent oil leakage. Connect with wire to prevent losing them. To clean governor valve, if necessary, pour kerosene into air inlet of carburetor while engine is running, varying the speed of the engine from high to low, thus opening and closing the valve. If it surges it may result from one of three causes: Governor lubrication bad, governor valve dirty or cable drive not steady due to back lash.

Never adjust the governor unless there is a reason for it. To set the governor turn the small hand wheel out for higher speed and in for lower speed. Do not fail to lock the hand wheel with yoke after setting, if a locking spring is not provided, and see that the yoke does not bind on hand wheel. The locking-pin and seal (1) are for the protection of the governor and the engine. Do not touch the valve screws (4). If grid valve of governor is jammed shut or open, clean out with kerosene. It is caused by particles of grit or dirt becoming lodged between grids.

CHAPTER IV

TRUCK MOTOR COOLING AND LUBRICATION

Why Cooling Systems are Necessary—Heat Loss in Average Motor—Cooling Systems Generally Applied—Direct Air Cooling Methods—Forced Water Circulation—Water Circulation by Natural System—Radiator Construction—Cooling Fan and Pump—Motor-Meter—Thermostat—Rayfield Thermostat—Lubricating Truck Engines—The Nash Oiling System—Mack A. C. Lubricating System—Plunger Pump for Oil Circulation—White Oil Pump Action—Wisconsin Oiling System—Packard Motor Lubrication.

Why Cooling Systems Are Necessary.—The reader should understand from Chapter II that the power of an internal combustion motor is obtained by the rapid combustion and consequent expansion of some inflammable gas. The operation in brief is that when air or any other gas or vapor is heated, it will expand, and that if this gas is confined in a space which will not permit expansion, pressure will be exerted against all sides of the containing chamber. The more a gas is heated, the more pressure it will exert upon the walls of the combustion chamber in which it is confined. Pressure in a gas may be created by increasing its temperature and inversely heat may be created by pressure. When a gas is compressed its total volume is reduced and the temperature is augmented.

The efficiency of any form of heat engine is determined by the power obtained from a certain fuel consumption. A definite amount of energy will be liberated in the form of heat when a pound of any fuel is burned. The efficiency of any heat engine is proportional to the power developed from a definite quantity of fuel with the least loss of thermal units. If the greater proportion of the heat units derived by burning the explosive mixture could be utilized in doing useful work the efficiency of the gasoline motor would be greater than that of any other form of prime mover. There is a great loss of heat from various causes,

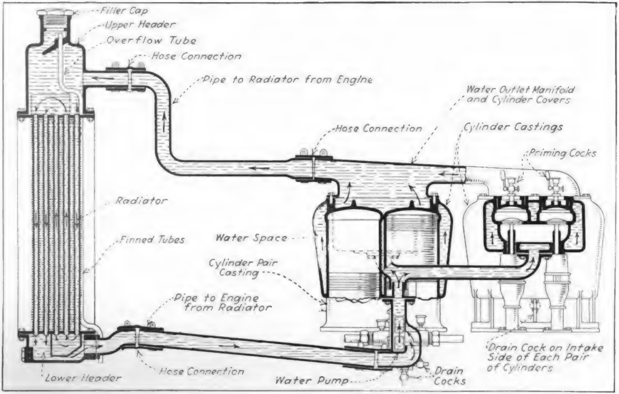

Filler Cap
Upper Header
Overflow Tube
Hose Connection
Pipe to Radiator from Engine
Water Outlet Manifold and Cylinder Covers
Hose Connection
Cylinder Castings
Priming Cocks
Radiator
Finned Tubes
Water Space
Cylinder Pair Casting
Pipe to Engine from Radiator
Drain Cock on Intake Side of Each Pair of Cylinders
Lower Header
Hose Connection
Water Pump
Drain Cocks

Fig. 113.—Cooling System of the Four-Wheel Drive Truck Showing Forced Circulation by Means of Centrifugal Water Pump. The Course of the Water is Plainly Indicated by the Arrows.

among which can be cited the reduction of pressure through cooling the motor and the loss of heat through the exhaust valves when the burned gases are expelled from the cylinder.

Heat Loss in Average Motor.—The loss through the water jacket of the average automobile power plant is over 35 per cent of the total fuel efficiency. This means that more than one-third of the heat units available for power are absorbed and dissipated by the cooling water. Another 35 per cent is lost through the exhaust valves, and but 30 per cent of the heat units are available to overcome motor friction and do useful work. The great loss of heat through the cooling systems cannot be avoided, as some method must be provided to keep the temperature of the engine within proper bounds. It is apparent that the rapid combustion and continued series of explosions would soon heat the metal portions of the combustion chamber and valves to a red heat if some means were not taken to conduct much of this heat away. The high temperature of the parts would burn the lubricating oil, even that of the best quality, and the piston and rings would expand to such a degree, especially when deprived of oil, that they would seize in the cylinder. This would score the walls, and the friction which ensued would tend to bind the parts so tightly that the piston would stick, bearings would be burned out, the valves would warp, and the engine would soon become inoperative.

Cooling Systems Generally Applied.—There are two general systems of engine cooling in common use, that in which water is heated by the absorption of heat from the engine and then cooled by air, and the other method in which the air is directed into the cylinder and absorbs the heat directly instead of through the medium of water. When the liquid is employed in cooling it is circulated through jackets which surround the cylinder casting and the water may be kept in motion by two methods. The one generally favored is to use a positive circulating pump of some form which is driven by the engine to keep the water in motion, as shown at Fig. 113. The other system is to utilize a natural principle that heated water is lighter than cold liquid and that it will tend to rise to the top of the cylinder when it becomes heated to the proper temperature and cooled water takes its place at the bottom of the water jacket. This very simple system is shown at Fig. 114.

Direct Air-Cooling Methods.—Air-cooling methods may be by radiation or convection. In the former case the effective outer surface of the cylinder is increased by the addition of flanges machined or cast thereon, and the air is depended on to rise from the cylinder as heated and be replaced by cooler air. This, of course, is found only on stationary engines. When a positive air draught is directed against the cylinder by means of the fan slip stream, as in an automobile, cooling is by convection and radiation both. Sometimes the air draught may be directed against the cylinder walls by some form of jacket which confines it to the heated portions of the cylinder. At the present time all trucks use water-cooled engines, and air-cooling methods are employed only on aviation and motorcycle engines, and two makes of passenger cars, the Franklin and the Holmes.

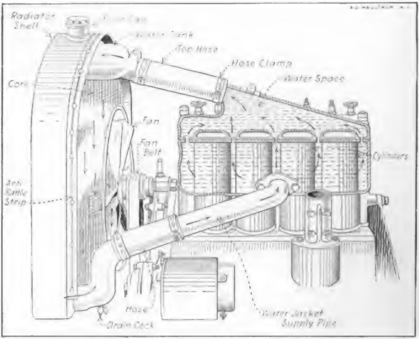

Radiator Shell
Filler Cap
Water Tank
Top Hose
Hose Clamp
Water Space
Core
Fan
Fan Belt
Cylinders
Anti Rattle Strip
Hose
Drain Cock
Water Jacket Supply Pipe

Fig. 114.—Overland Thermo-Syphon Cooling System.

Water Circulation by Natural System.—Some automobile engineers contend that the rapid water circulation obtained by using a pump may cool the cylinders too much, and that the temperature of the engine may be reduced so much that the efficiency will be lessened. For this reason there is a tendency on passenger cars to use the natural method of water circulation, as the cooling liquid is supplied to the cylinder jackets just below the boiling point, and the water issues from the jacket at the top of the cylinder after it has absorbed sufficient heat to raise it just about to the boiling point.

As the water becomes heated by contact with the hot cylinder and combustion chamber walls it rises to the top of the water jacket, flows to the cooler, where enough of the heat is absorbed to cause it to become sensibly greater in weight. As the water becomes cooler, it falls to the bottom of the radiator and it is again supplied to the water jacket. The circulation is entirely automatic and continues as long as there is a difference in temperature between the liquid in the water spaces of the engine and that in the cooler. The circulation becomes brisker as the engine becomes hotter and thus the temperature of the cylinders is kept more nearly to a fixed point. With the thermo-syphon system the cooling liquid is nearly always at its boiling point, whereas if the circulation is maintained by a pump the engine will become cooler at high speed and will heat up more at low speed.

With the thermo-syphon, or natural system of cooling, more water must be carried than with the pump-maintained circulation methods. The water spaces around the cylinders should be larger, the inlet and discharge water manifolds should have greater capacity, and be free from sharp corners which might impede the flow. The radiator must also carry more water than the form used in connection with the pump, because the brisker pump circulation maintains the engine temperature at a lower point. The simplicity of such a system is evident by referring to Fig. 114, but most truck designers favor the positive pump-induced circulation because a truck motor is a heavy duty type and it must be cooled adequately.

Forced Water Circulation.—The water is drawn from the lower header of the radiator by the pump and is forced through a manifold to the lower portion of the water jackets of the cylinder. It becomes heated as it passes around the cylinder walls and combustion chambers, and the hot water passes out of the top of the water jacket to the upper portion of the radiator. Here it is divided into thin streams and directed against comparatively cool metal, which abstracts the heat from the water. As it becomes cooler it falls to the bottom of the radiator, because its weight increases as the temperature becomes lower. By the time it reaches the bottom of the radiator, its temperature has been considerably reduced and it may be utilized again for cooling purposes. Typical truck cooling systems and details of their components are now to be described.

Mack A. C. Cooling System.—The cooling system shown at Fig. 115 is that used on the Mack A. C. truck and is a distinctive

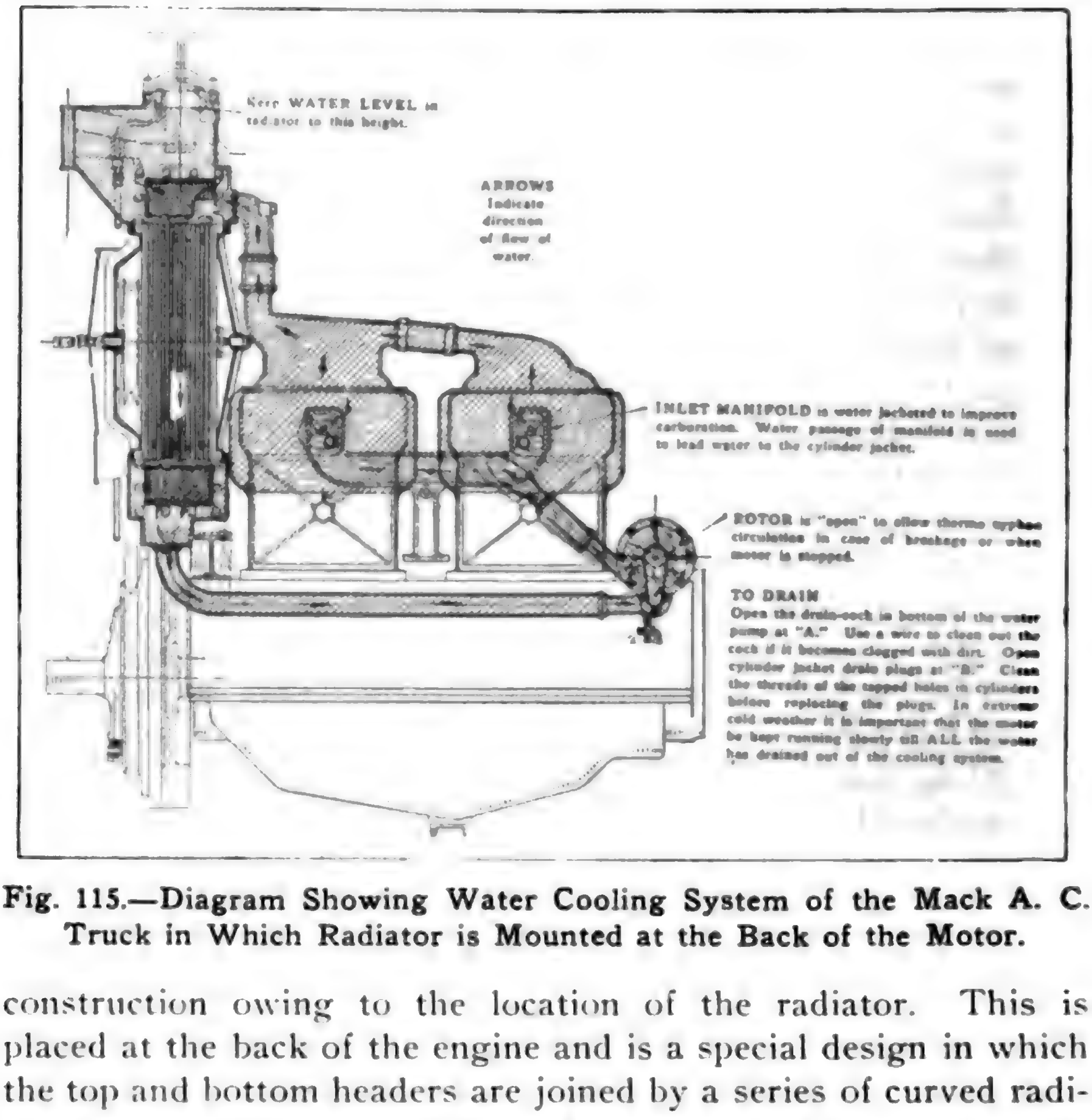

Keep WATER LEVEL in radiator to this height.
ARROWS Indicate direction of flow of water.
INLET MANIFOLD is water jacketed to improve carburetion. Water passage of manifold is used to lead water to the cylinder jacket.
ROTOR is "open" to allow thermo syphon circulation in case of breakage or when motor is stopped.
TO DRAIN
Open the drain-cock in bottom of the water pump at "A." Use a wire to clean out the cock if it becomes clogged with dirt. Open cylinder jacket drain plugs at "B." Clean the threads of the tapped holes in cylinders before replacing the plugs. In extreme cold weather it is important that the motor be kept running slowly till ALL the water has drained out of the cooling system.

Fig. 115.—Diagram Showing Water Cooling System of the Mack A. C. Truck in Which Radiator is Mounted at the Back of the Motor.

construction owing to the location of the radiator. This is placed at the back of the engine and is a special design in which the top and bottom headers are joined by a series of curved radiator tubes at the center of which is a suction fan to draw air through the tube assembly. This fan is driven from the flywheel by means of a substantial V-belt. The inlet manifold is water-jacketed to improve carburetion, and the water passage in the inlet pipe is used to lead water to the cylinder jackets. The pump draws water from the bottom of the radiator and is of the open rotor type. The water jackets and piping are of large size, and in event of failure of the pump to work, due to any cause the water could circulate by the thermo-syphon or natural system and still keep the engine at a safe working temperature.

Radiator Construction.—While the radiator is a relatively simple member in operation, it is rather complicated in construction. The tubes through which the water passes in its flow from the upper to the lower radiator tanks are a variety of sizes and shapes, as shown at Fig. 116. The honeycomb system, which is depicted at A, B and C, uses water passages of relatively small area and provides rapid cooling due to the efficient transmission of heat from the thin columns of water to the large surface of the metal walls surrounding it. In order to be successful for motor trucks a honeycomb construction must be more substantially made than that form used on passenger cars. The forms

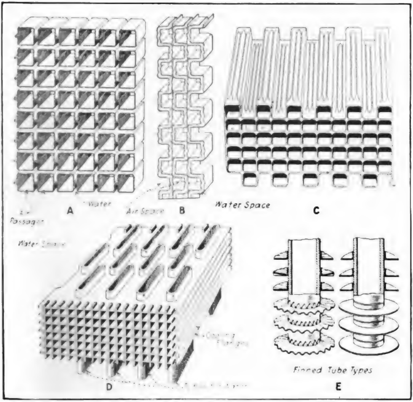


Fig. 116.—Various Types of Water Cooling Tubes Used in Radiator Construction. A, B and C—Honeycomb Sections. D—Flat Tubes with Flanges. E—Finned Round Tube Types Used in Truck Radiator.

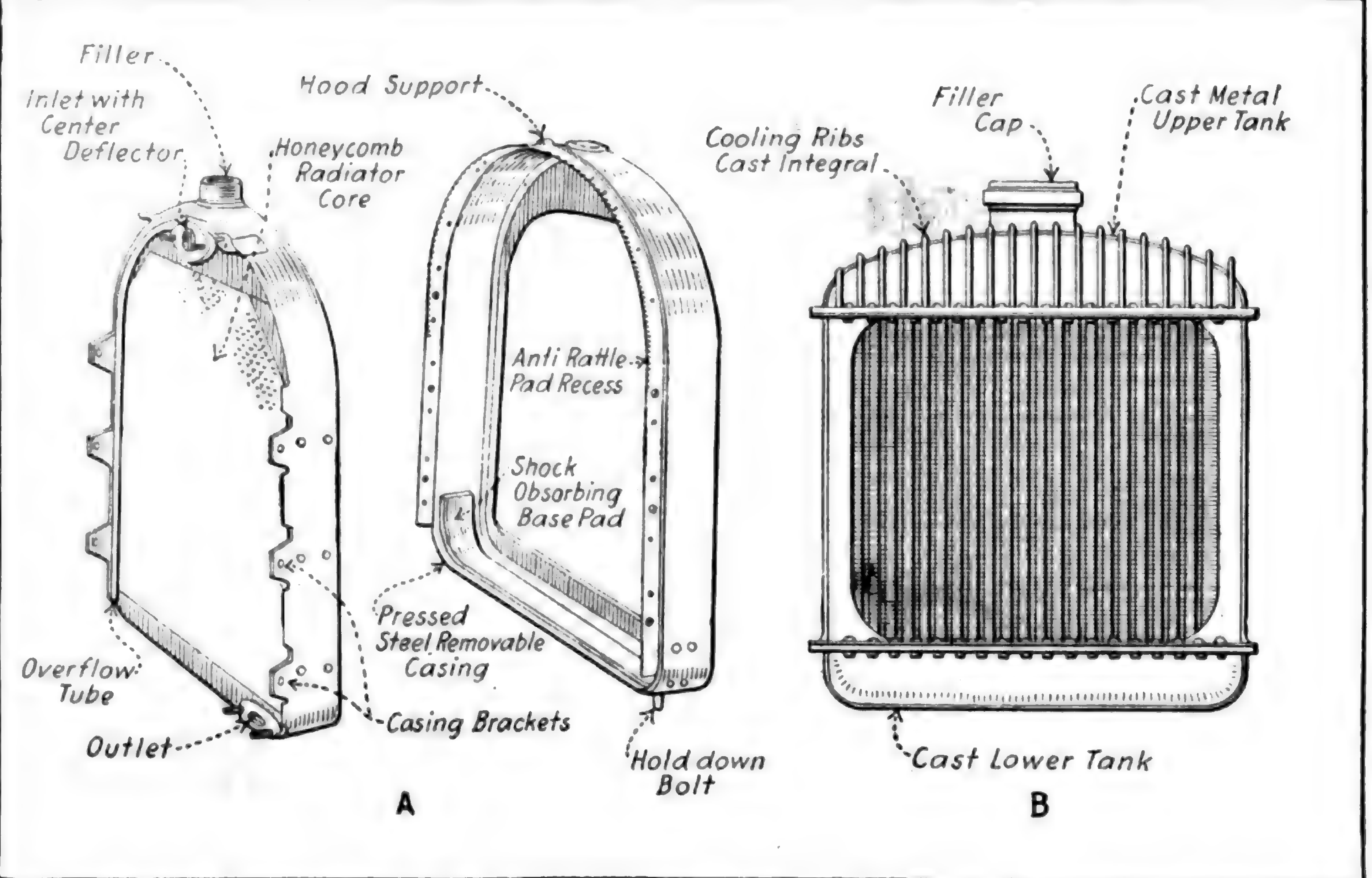

Filler
Inlet with Center Deflector
Honeycomb Radiator Core
Hood Support
Overflow Tube
Outlet
Casing Brackets
Pressed Steel Removable Casing
Anti Rattle Pad Recess
Shock Obsorbing Base Pad
Hold down Bolt
A
Cooling Ribs Cast Integral
Filler Cap
Cast Metal Upper Tank
Cast Lower Tank
B

Fig. 117.—How Radiators Vary in Construction. A—Modern Passenger Car and Light Truck Type Having Removable Honeycomb Core and Pressed Steel Exterior Shell. B—Common Motor Truck

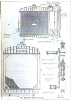


Fig. 118.—Diagrams Showing Methods of Supporting Radiators. A—Radiators Held by Trunnion Bearings. B—Radiator Supported by Pressed Steel Cross Member and Held by Retention Bolts at the Bottom. C—White Radiators Suspended by Shock Absorbing Spring Support Member.

of tubes shown at D and E are very satisfactory for motor truck radiator construction, because they do not call for the multiplicity of soldered joints found in the cellular or honeycomb construction, and are not so apt to leak due to opening of the joints from vibration. In all cases the tubes are provided with cooling flanges or fins to assist in radiating the heat. The radiators used on light trucks and "speed" wagons are provided with a detachable core which fits into a removable pressed steel casing having a shock-absorbing base pad as outlined at A, Fig. 117.

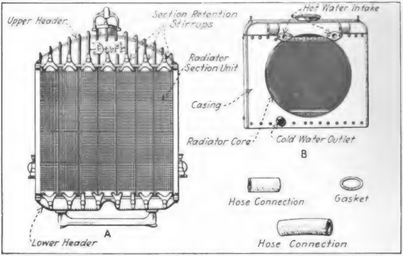

Upper Header
Dart
Section Retention Stirrups
Hot Water Intake
Radiator Section Unit
Casing
Radiator Core
Cold Water Outlet
B
Hose Connection
Gasket
A
Lower Header
Hose Connection

Fig. 119.—Removable Sections in the Dart Truck Radiators Making Repairs Easy. Radiator Shown at B is the Type Used for International Harvester Motor Trucks.

On the heavier trucks the radiator construction is generally as shown at B. Cast iron or aluminum upper and lower headers are joined together by a substantial frame which takes all of the strain off the tubes which extend between the upper and lower water compartments, and through which the cooling water flows to be cooled. The upper tank usually has cooling ribs cast integrally at a substantial filler opening. Methods of supporting radiators are shown at Fig. 118.

The Dart Motor Truck Co. has equipped some of its models with a distinctive design of radiator shown at Fig. 119, A. There are cast tanks at top and bottom, the top tank being finned to increase radiation and equipped with a unique cap, which cannot be lost. The core is composed of seven separate and independent sections held in the casing by separate clamps. These cores are of the honeycomb type, four inches deep, giving large cooling surface. In case of damage by accident any of these sections can be removed by loosening two bolts. This does not disturb the other sections, as each section has separate openings into the top and bottom tanks and is equipped with individual gaskets.

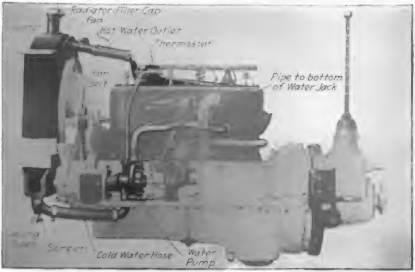


Fig. 120.—Simplicity and Strength of the Packard Motor Truck Power Plant Cooling System. Diagram Shows Important Elements Including the Water Pump and Thermostat.

Plugs for the openings in the top and bottom tanks and extra gaskets are furnished with the truck and are carried in the toolbox. Repairs to any section can be made without laying up the truck, and replacements are economical because only the sections damaged need be purchased. Both sides of the radiator are connected with the circulation system, giving an even flow of water. The total capacity of the radiator is approximately fifteen gallons.

The radiator construction of the I. H. C. trucks, which is placed at the rear of the motor, is shown at Fig. 119, B, also some of the short hose connections needed to join it to the engine.

Cooling Fan and Pump.—Other important parts of the cooling system are the fan and the pump. The centrifugal pump, such as outlined at Fig. 121, is generally employed. This consists of a cast bronze paddle-wheel or rotor member which revolves in a case of non-corrosive material. The water flows to the center of the paddle-wheel and is thrown to the outer circumference by centrifugal force as the rotor revolves. An outlet pipe on the outer periphery of the pump casing carries off the water from the interior.

Cooling fans are usually of the construction shown at Fig. 122. They generally consist of a hub member revolving on anti-friction bearings carrying lugs to which a series of angularly disposed fan blades are riveted. The fan assembly is strengthened by a circular rim of sheet metal attached to the tips of the blades and is driven from the engine crankshaft by means of a flat leather belt or one of V section. Arrangements are always provided so that the belt tension may be maintained at the proper point by a readily accessible adjustment.

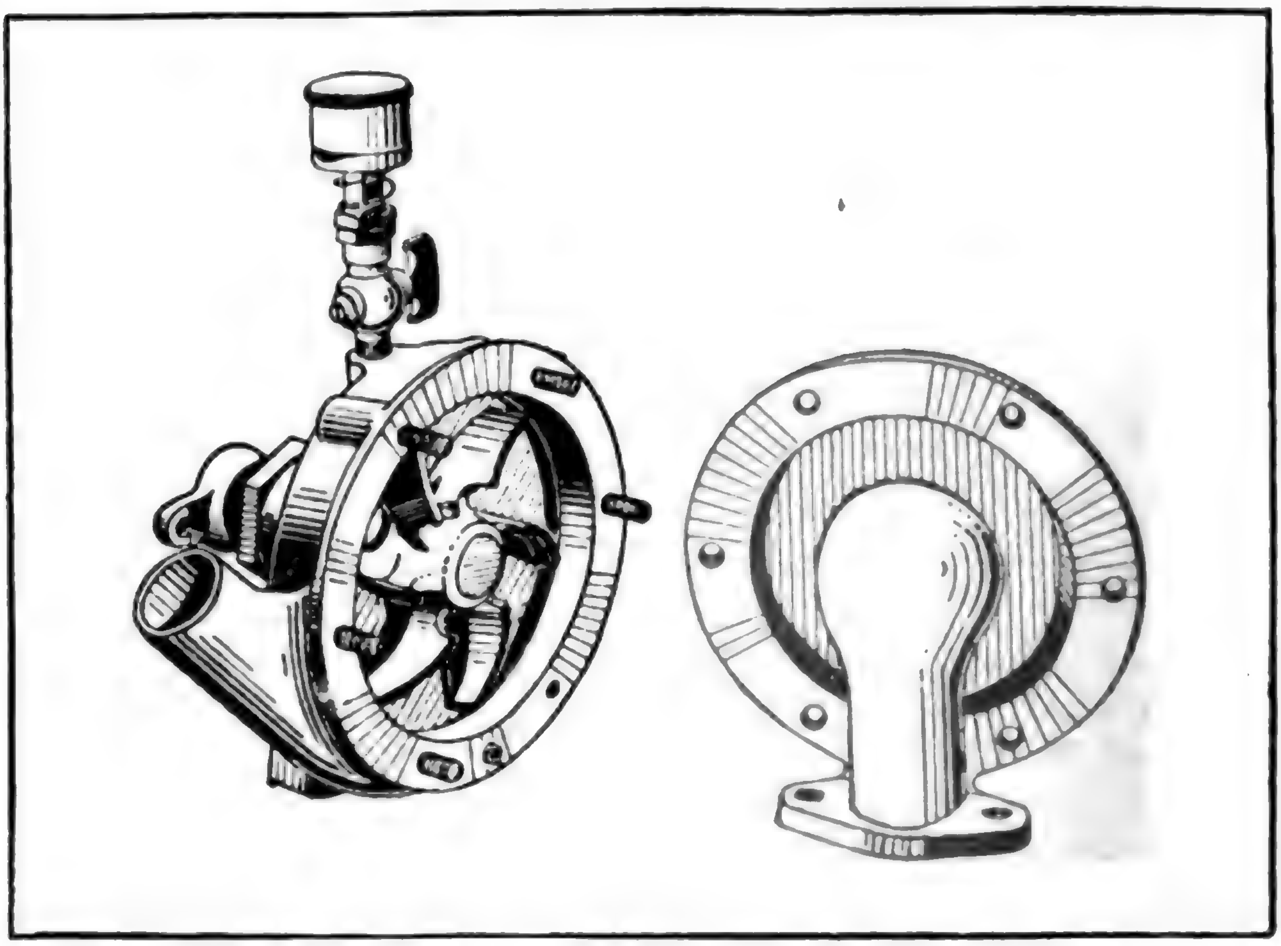


Fig. 121.—Centrifugal Water Pump of International Harvester Trucks with Cover Removed to Show Internal Construction.

Motor-Meter.—All Packard D model trucks are equipped with a motor-meter on the radiator cap to show the temperature of the water in the radiator. The motor will show its greatest efficiency with the water in the cooling system at about 170 degrees. It should be kept as nearly to this point under all atmospheric conditions as is possible. Overheating is most generally caused by running with too rich a mixture or with the spark too far retarded, carbon in the cylinders, a loose fan belt, insufficient lubrication, improperly timed valves, or by the clogging of the system in any way which will prevent free circulation of the water. Under this condition the motor will knock easily under load with possible damaging results. Failure of the water to reach proper temperature after motor has been running for some time is generally caused by atmospheric condi-

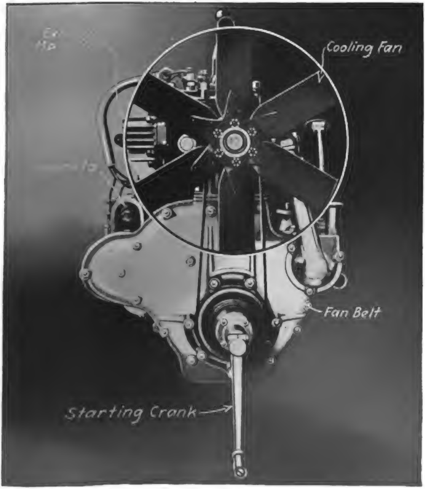


Fig. 122.—**Front End View of the White Model G. N. Motor Truck Engine Showing Cooling Fan and Method of Driving by Flat Belt.**

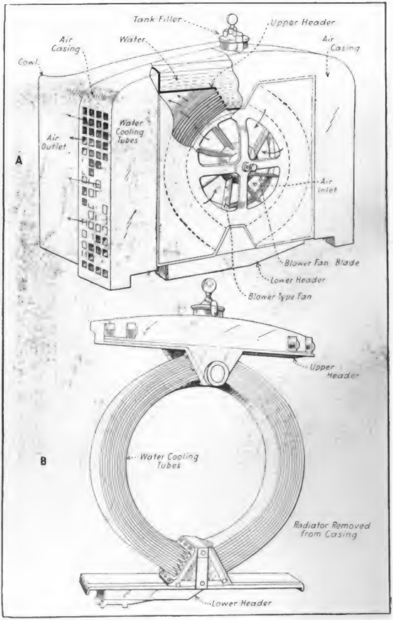

Tank Filler
Upper Header
Air Casing
Water
Air Casing
Cowl
Water Cooling Tubes
Air Outlet
A
Air inlet
Blower Fan Blade
Lower Header
Blower Type Fan
Upper Header
B
Water Cooling Tubes
Radiator Removed from Casing
Lower Header

Fig. 123.—A Solderless Radiator for Motor Trucks. A—Showing Blower Type Air Circulating Fan. B—The Radiator Tubes and Water Headers Removed from Air Casing.

tions, resulting in improper vaporization of the gasoline and a consequent lack of power. In cold weather the necessary heat for proper running should be conserved by using a hood or radiator cover, or disconnecting the fan belt, if necessary.

Thermostat.—Packard Model E trucks are equipped with a thermostat located at the forward end of the water outlet header on the top of the cylinder block, by-passing water to the pump inlet side until reaching the proper temperature to permit efficient running of motor, as shown at Fig. 120. A by-pass tube connects the thermostat housing with the inlet side of the water pump. Valves controlling the entrances to the radiator and the by-pass tube are carried on a shaft, actuated by the action of the thermostat syphon. Normally, when the water is cold, the radiator valve is closed and the by-pass inlet valve open, allowing the water to circulate through the cylinder jackets and back to the pump without entering the radiator. The water becoming heated causes the syphon to expand and open radiator inlet valve, at the same time closing the by-pass valve, making it necessary for all water to circulate through the radiator. When inspection of thermostat is necessary, disconnect the rubber hose between radiator and cylinder water outlet. Remove the nut and washer in rear of the thermostat housing; also the four nuts in front of the housing. Remove the thermostat and immerse in a pail of water heated to a temperature of 130° to 140° F. At this temperature the syphon should expand three-eighths inch, thereby opening radiator outlet passage and closing by-pass. Model D trucks are not equipped with thermostats.

The Rayfield Thermostat.—Engine efficiency is usually highest with reference to power production just before the water in the cooling system boils. If it is maintained at this point the heat is effectively diffused and there should be good fuel and lubricant economy.

Starting any engine depends largely upon the combustibility of the fuel. If the gasoline or other oil will volatilize so that the cylinders can be filled with a gas that will ignite, the charges will burn and power will be developed, but there will be irregularity of operation until the water of the cooling system is heated. The main reason why engine function improves as it is operated is that the fuel is heated and becomes more and more combustible until it reaches the height of power production with the carburetor setting.

The water of the thermo-syphon cooling system will not begin circulation until it has been sufficiently heated to have movement by gravity, but the water of the pump or circulating cooling system will begin to circulate as quickly as the engine and pump is started. Naturally more time is required for heating the water in movement than when it circulates by gravity, but as pump circulation is more general than thermo-syphon a very large number of the cars and trucks in use heat slowly, this condition being the more pronounced with the fall of temperature.

If the engine is cooled by water, circulation by pumpage and the height of power production cannot be realized until the cylinder jacket is to a temperature of at least 180 degrees. For engines of this type a thermostatic valve has been made by the Beneke & Kropf Manufacturing Co., which has been given the trade name Rayfield. The object of the valve is to prevent the circulation of water in the cylinder jacket until the temperature is from 155 to 160 degrees, by-passing the water forced by pump through the radiator. As the valve will open gradually the movement is restricted until the maximum temperature is reached, when the circulation is full and the cooling is in ratio to the speed of the engine and the draft of air through the radiator. Obviously the cooling system must be such that the engine will not overheat in the hottest day of summer, and in at least reasonable condition for use.

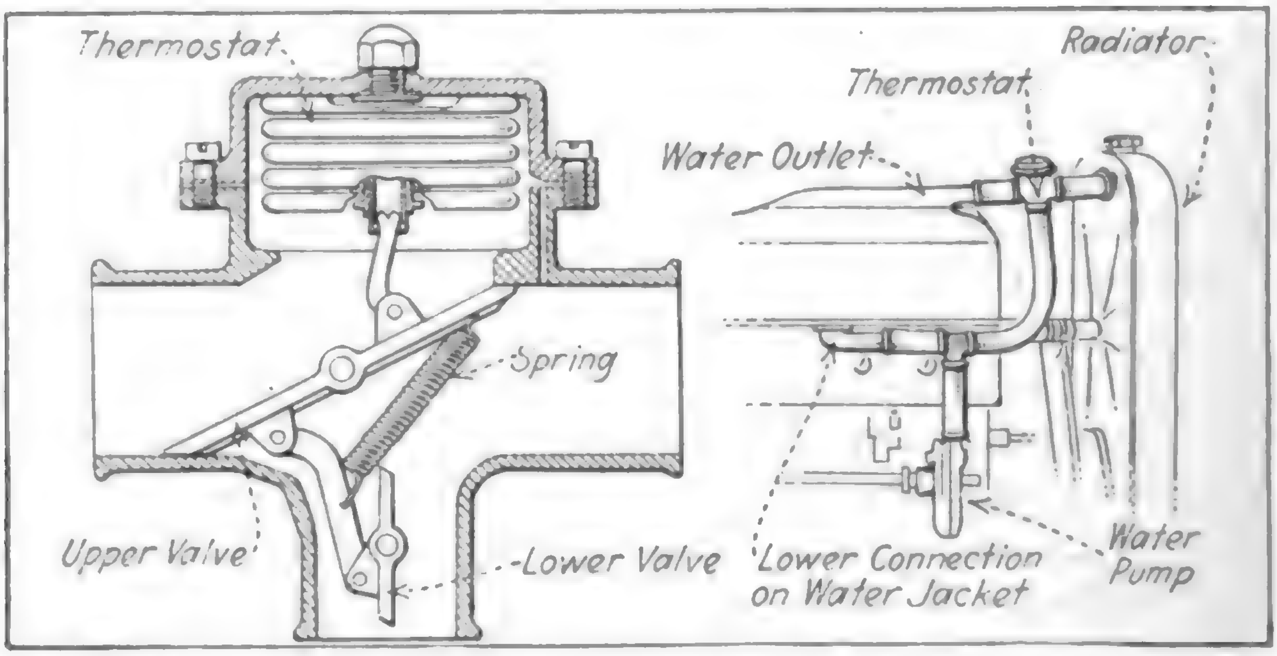


Fig. 123A.—The Rayfield Thermostat for Use in Cooling Systems Not Already Provided With a Device of this Nature.

The Rayfield thermostat is extremely compact and it may be installed in any cooling system designed for pump circulation.

It is placed between the engine and the radiator, on the radiator intake connection, and a by-pass hose is connected from the thermostat to the radiator outlet between the pump and the cylinder jacket. The thermostat is operated by the variance of temperature on an expanding one-piece diaphragm. The valve mechanism of the thermostat is such that when the engine is started the water is not forced through the cylinder jacket, but by-passes through the outlet manifold, the thermostat and the radiator intake and radiator. In other words, the circulation is maintained through the radiator, but not through the cylinder jacket until the water in the jacket is heated to 155 or 160 degrees.

At this temperature the diaphragm of the thermostat expands and opens the valve, so that the water passing will maintain the minimum temperature. The thermostat is constructed of bronze and there is no reason for deterioration, so that normally it ought to be efficiently serviceable during the life of an engine. A safety device has been incorporated in the construction, so that should the diaphragm become punctured the valve will open and the normal circulation will continue. Claim is made that the thermostat when installed on an engine will economize the fuel, prevent gasoline leaking to the crankcase and minimize the accumulation of carbon on the spark plug electrodes and the valves, to say nothing of making practical development of greater power of the engine.

Lubricating Truck Engines.—It is important to reduce friction at the various bearing surfaces of the motor truck engine in order to secure continued operation without rapid depreciation of parts and to prevent seizing of the moving members due to excessive friction and heat. All of the parts of an engine that have movement relative to the others, whether the speed of movement is high or low, or of a reciprocating or continuous rotary nature or whether it is continuous or intermittent in action, must be provided with adequate quantities of lubricating oil of the proper quality. Motor truck engine lubrication systems should not only be positive in action, but should not be susceptible to changes in weather conditions. The lubricant should be supplied in an automatic manner, as the oil feed should start as soon as the engine begins to turn, and the supply should be stopped as soon as the engine ceases to function. Practically all systems of motor truck lubrication use a mechanically operated oil pump to insure continued circulation of oil. In some systems the pump supplies the lubricant to troughs in the base of the engine into which the connecting rod big ends dip as they rotate. A constant level of oil is maintained in these troughs, the surplus draining down into a separate chamber under the crankshaft called the sump, which cannot be reached by the connecting rod and from which the oil is drawn by the pump.

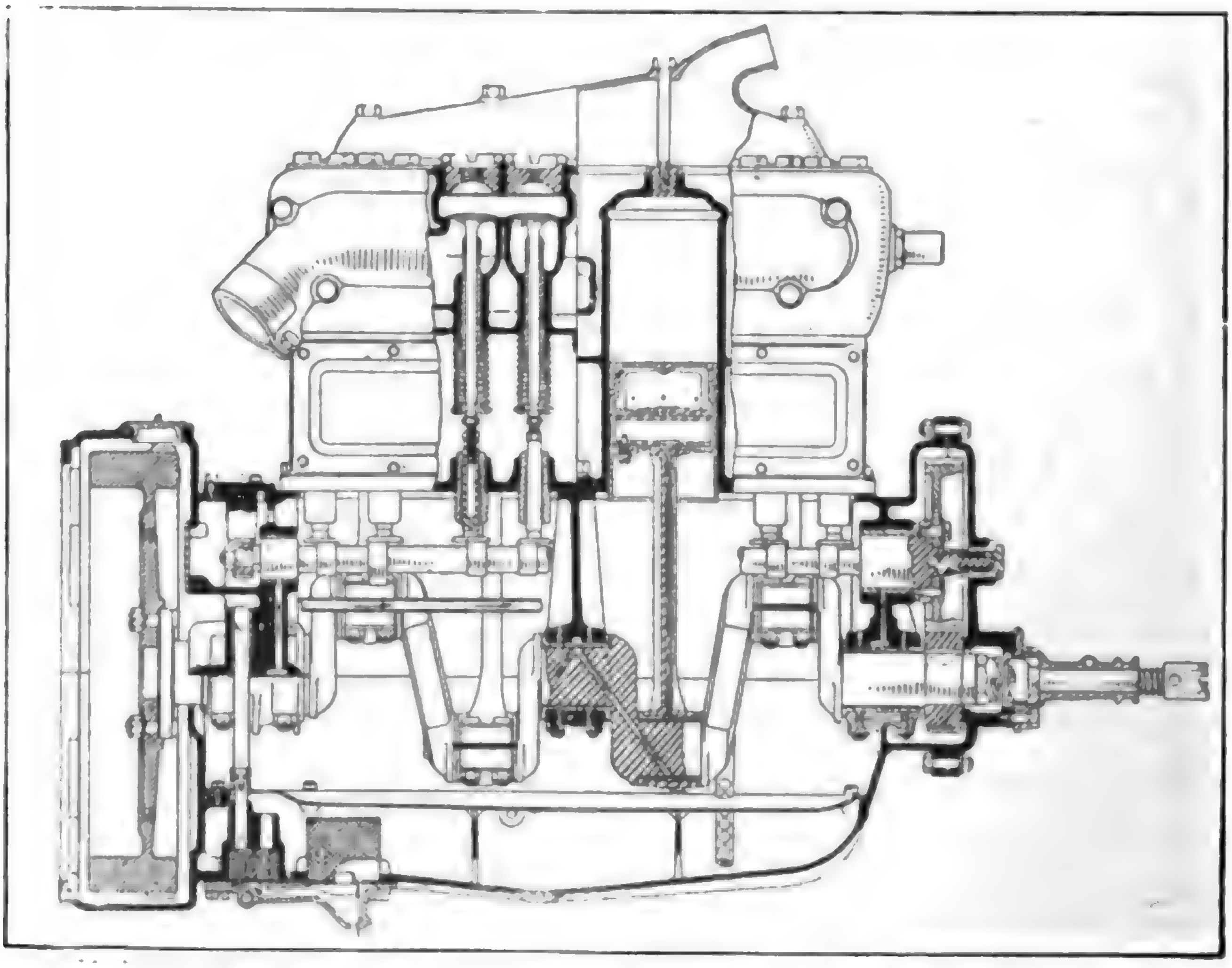


Fig. 124.—Longitudinal Sectional View of Motor Truck Engine Showing Forced Feed Lubricating System Generally Employed.

Another system, known as the "dry sump" method, does not depend on the big ends of the connecting rods dipping into oil-troughs. The oil is drawn from the sump about as fast as it collects therein, and is forced to the various bearing points under fairly high pressure. Passages are machined in the main bearings and in the crankshaft, and surplus oil is thrown off from the revolving crankpin bearings in the form of a constant spray which tends to lubricate all of the interior parts of the engine. Owing to the rapid circulation of oil it may be used over and over again for quite a period of time, as it is cooled in the engine base and before passing into the pump again, and from that point to the bearings it is filtered by a screen of wire gauze and all dirt removed. A simple gauge on the side of the engine crankcase indicates the amount carried in the sump, and new oil may be introduced into the engine interior by means of a combined breather pipe and engine filler opening attached to the crankcase.

The Nash Oiling System.—The lubricating system shown at Figs. 124 and 125 is the pressure type (operating at a maximum of thirty-five pounds) operated by a gear oil pump drawing oil from reservoir through wire screen to pump through a vertical tube to horizontal distributing tube inside of crankcase. This tube feeds oil to ducts running to crankshaft bearings and camshaft bearings. The crankshaft is drilled through the crankshaft cheeks, oil being forced through the holes to the connecting rod bearing, and from there through a copper tube on the outside of connecting rod to the wristpin bearing. The oil forced out from the bearings by pressure lubricates cylinder walls, pistons and valve pushrods and falls down into the base and back to the oil reservoir. The overflow through the checkvalve at the front of engine goes to the timing gear housing, and from there by gravity back to the oil reservoir and so through oil screen to pump.

The oil is drawn from the crankcase bottom into the pump at one end, and is carried around between the teeth of both gears, next to the sides of the pump body to the other end of the pump body. The oil is prevented from returning by the teeth of the two gears meshing together (as one gear drives the other). It escapes through the pump outlet passage into a pipe connection with a main oil passage in the crankcase.

The oil pump is of the gear type, and is bolted to the bottom of the left side of the crankcase oil base. It is driven from the camshaft by a pair of spirals, through a vertical shaft made of cold-rolled steel. The shaft is .625 inch in diameter and 13.5625 inches long. It revolves in a cast iron guide lined with a die-cast white metal bushing. The bottom of the shaft is flattened and fits into the upper end of the oil pump gearshaft. The upper end of the shaft extends through the top of the crankcase and is notched to receive the driving end of the governor flexible shaft. The two spur gears in the pump are of hardened steel—one is forged integral with the pump gear shaft, the other with a small shaft on which it runs in the body of the pump. These gears

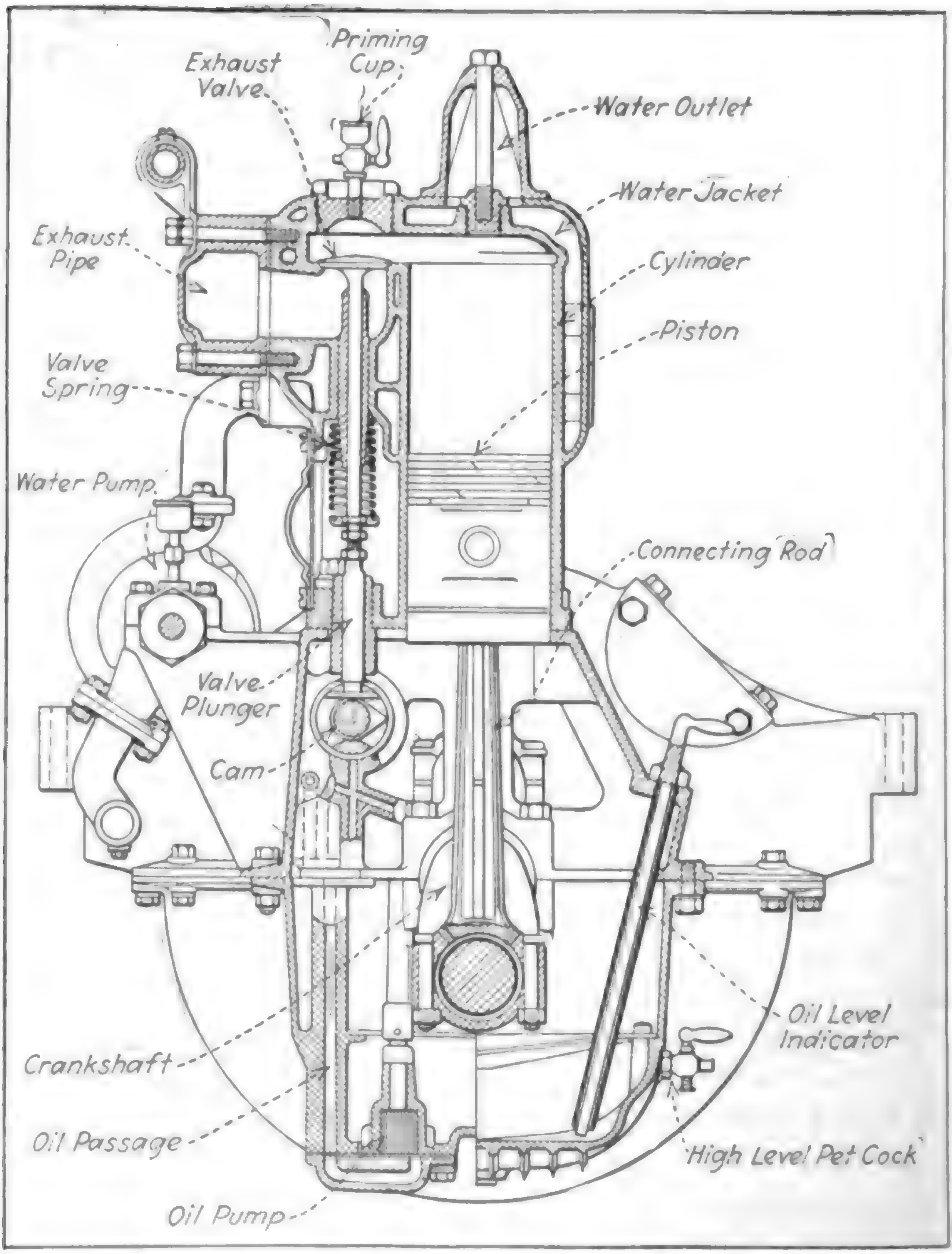

Priming Cup
Exhaust Valve
Water Outlet
Water Jacket
Exhaust Pipe
Cylinder
Piston
Valve Spring
Water Pump
Connecting Rod
Valve Plunger
Cam
Oil Level Indicator
Crankshaft
Oil Passage
High Level Pet Cock
Oil Pump

Fig. 125.—End Sectional View of Motor Truck Engine Showing Cored Passages Through Which Lubricating Oil is Forced to the Bearing Points by Gear Pump Pressure.

have each 12 teeth (12 pitch)—a pitch diameter of 1 inch, outside diameter 1.166 inch and a face of 1.25 inch.

Below the level of the oil pump and bolted to the crankcase there is a cast iron oil pan sediment filter over the top of which an inverted cylindrical screen is placed. The oil from the filter flows into the pump, thus allowing sediment to settle at the

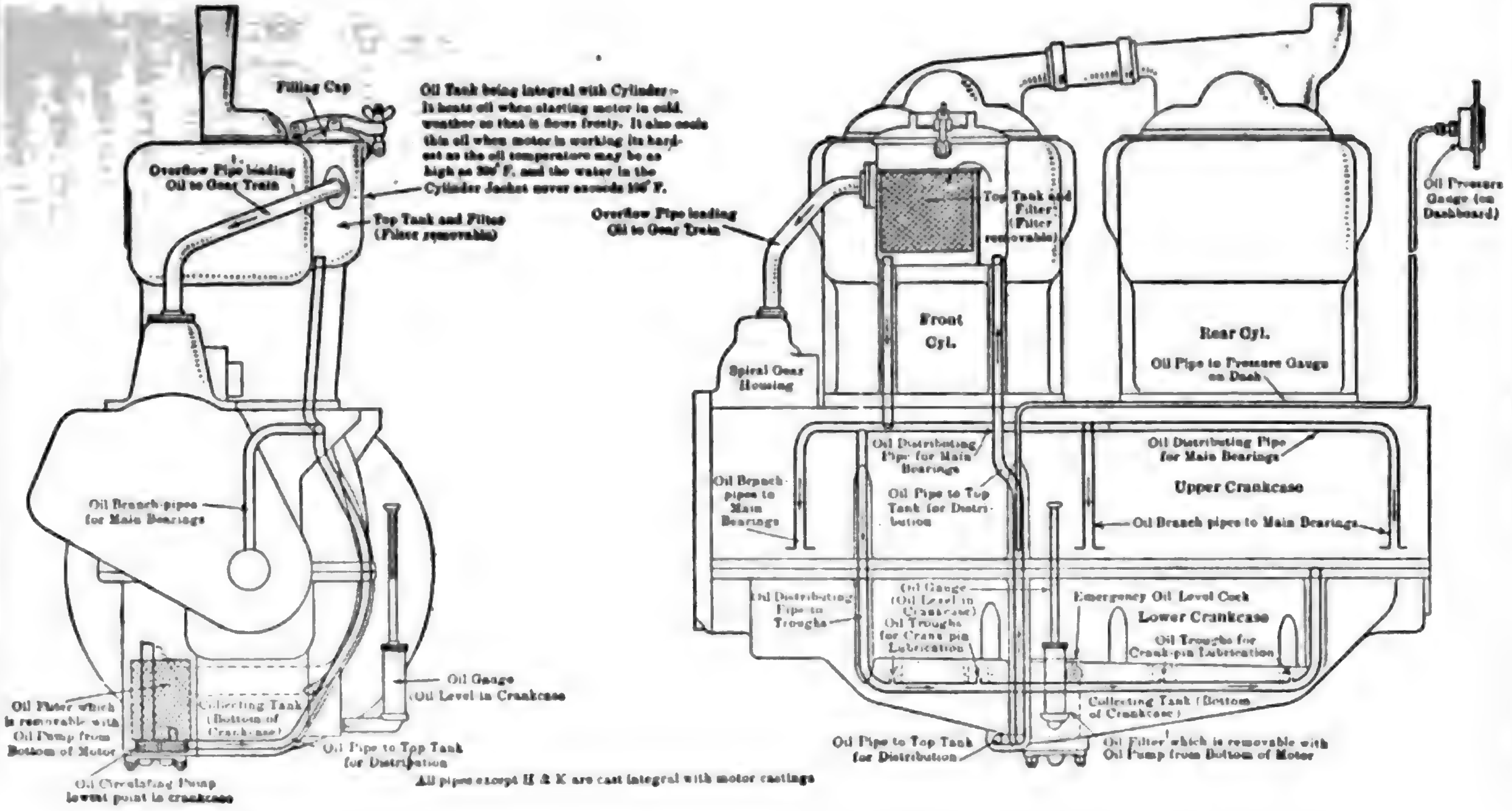

Filling Cap
Overflow Pipe leading Oil to Gear Train
Oil Tank being integral with Cylinder—It heats oil when starting motor in cold weather so that it flows freely. It also cools this oil when motor is working its hardest as the oil temperature may be as high as 300° F. and the water in the Cylinder Jacket never exceeds 195° F.
Top Tank and Filter (Filter removable)
Oil Branch-pipes for Main Bearings
Oil Gauge (Oil Level in Crankcase
Oil Filter which is removable with Oil Pump from Bottom of Motor
Collecting Tank (Bottom of Crankcase)
Oil Pipe to Top Tank for Distribution
Oil Circulating Pump lowest point in crankcase
All pipes except H & K are cast integral with motor castings
Overflow Pipe leading Oil to Gear Train
Top Tank and Filter (Filter removable)
Front Cyl.
Rear Cyl.
Oil Pipe to Pressure Gauge on Dash
Oil Pressure Gauge (on Dashboard)
Spiral Gear Housing
Oil Distributing Pipe for Main Bearings
Oil Distributing Pipe for Main Bearings
Upper Crankcase
Oil Branch pipes to Main Bearings
Oil Pipe to Top Tank for Distribution
Oil Branch pipes to Main Bearings
Oil Distributing Pipe to Troughs
Oil Gauge (Oil Level in Crankcase)
Oil Troughs for Crank pin Lubrication
Emergency Oil Level Cock
Lower Crankcase
Oil Troughs for Crank-pin Lubrication
Collecting Tank (Bottom of Crankcase)
Oil Pipe to Top Tank for Distribution
Oil Filter which is removable with Oil Pump from Bottom of Motor

Fig. 126.—Diagrams Outlining Lubrication System of the Mack A. C. Motor Truck Engine.

bottom. A 0.5 inch plug is provided to allow the sediment to be drained off periodically. In the pressure system of lubrication it is important to keep the bearings tight so that oil passages will not leak at this point. Any leakage would prevent the full quantity of oil reaching all parts of the system. If there was marked leakage at any point—for example, at the middle main bearing—the other main bearings might be starved and the cylinders and the bearing that was loose would receive an excessive supply of oil. The oil supply and pressure are regulated by adding or removing washers under the oil pressure valve screw, which increases or decreases the spring tension, on the ball check valve. To ascertain if the oil pump is working on the Nash truck, open the petcock, which is on the right side of the engine near the flywheel.

Mack A. C. Lubricating System.—The lubricating system of the Mack A. C. truck motor is shown at Fig. 126. In this the oil tank is cast integrally on the outside of the cylinder water jacket. It heats oil in cold weather and helps to cool it in warm weather or when the motor is working very hard. Under such conditions the oil temperature may be as high as 300° F., and the water in the cylinder jacket never exceeds 190° F. The oil flows from the tank to the oil pump, which circulates it through oil branch pipes to the main bearing. An oil pressure gauge on the dash board indicates whether or not the oil is flowing properly. In addition to the positive supply to the main bearing, oil troughs are provided into which the big end of the connecting rod dip, to secure splash lubrication. Practically all pipes in the interior of the crankcase are cast integrally with the motor casting. An overflow pipe leads from the top tank to the timing gear train, so that the tank cannot overflow.

Plunger Pump for Oil Circulation.—While most of the lubricating systems use oil supply pumps of the gear type, a number of engines are provided with plunger pumps. The end view of the engine shown at Fig. 127 outlines the manner of installing a simple plunger pump so that it will work from an eccentric on the camshaft. A spring keeps the plunger in contact with the eccentric and provides the pressure which forces the piston or pump plunger inward on its suction stroke. When the plunger moves in the ball check valve at the bottom it is lifted up and oil is drawn from the sump through the suction pipe. On the return stroke of the pump plunger the suction check valve is closed

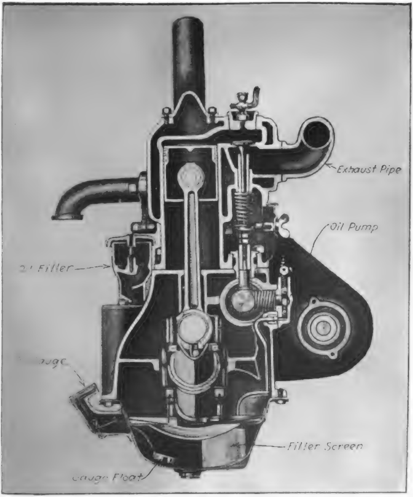


Fig. 127.—End Sectional View of Motor Truck Power Plant Showing Parts of Lubricating System and How Oil May Be Circulated by a Single Plunger Pump Actuated by an Eccentric of the Camshaft.

and the discharge check valve at the top of the pump is forced from its seat and the oil circulated through the distributing system. Owing to the rapidity of movement of the pump plunger it is of very short stroke.

White Oil Pump Action.—The mechanical oil pump action used on some White models is as follows: The oil pump rockers are mounted in the oil pump cover and are actuated by the oil pump crank. On the oil pump crank are eccentrics which move the rockers up and down. The rockers, in turn, move the plungers. The stroke of the pump plunger is varied by means of adjusting nuts, which, in being turned, screw in and out a stud connected to the rocker. As the rocker end is moved up or down, the stroke is made either shorter or longer. The lubricating oil tank is an aluminum casting with an opening in the top, in which is inserted a strainer. The opening is covered with a hinged cover. At the bottom of the tank is the oil reservoir screen held in place with a pipe fitting. The oil reservoir is held in place on the left hand side of the dash by screws. The oiling system is shown at Fig. 128.

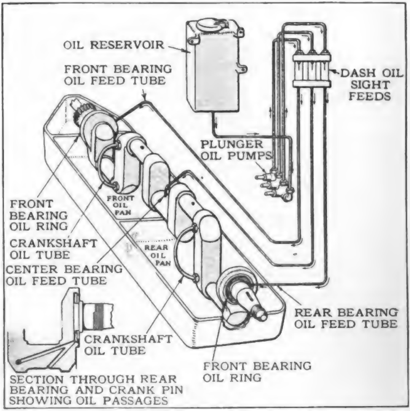

OIL RESERVOIR
FRONT BEARING OIL FEED TUBE
DASH OIL SIGHT FEEDS
PLUNGER OIL PUMPS
FRONT BEARING OIL RING
FRONT OIL PAN
CRANKSHAFT OIL TUBE
REAR OIL PAN
CENTER BEARING OIL FEED TUBE
REAR BEARING OIL FEED TUBE
CRANKSHAFT OIL TUBE
FRONT BEARING OIL RING
SECTION THROUGH REAR BEARING AND CRANK PIN SHOWING OIL PASSAGES

Fig. 128.—Diagram Outlining Lubrication System of Some of the White Truck Models.

The oil sight feed assembly includes the three inlet and the three outlet oil sight feed elbows. These form connections from the three oil leads to the pump. The sight feed glasses are held in place by the sight feed cap and valve seats, under which there is a gasket, and the whole retained in the oil sight feed casting. The latter is held in place by screws on the dash. In the operation of the car, filtered oil is placed in the oil reservoir until the same is full. The course of the oil from the tank is as follows: From the tank, which is mounted on the dash under the hood, by gravity through a tube to the pump on the lower right side of the engine crankcase, thence by force feed through three separate pipes to the sight feed indicators, on the dash, thence by gravity through two of the tubes to the crankshaft collector rings, thence through oil ways in the crankshaft to the connecting rod bearings, and through the third tube to the crankshaft center bearing. The surplus and thrown-off oil falls into the crankcase basin.

The flow of oil from each of the three oil plungers through their respective sight feeds to bearings is as follows: The forward plunger feeds through right sight feed to rear collector ring and third and fourth connecting rod bearings. The center plunger feeds through the center sight feed to center bearing. The rear plunger feeds through the left sight feed to front collector ring and first and second connecting rod bearings. The sight feed indicators on the dash show the driver at all times the amount of oil which is being fed.

Wisconsin Oiling System.—A combined splash and force feed oiling system is used, as shown clearly at Fig. 129. A gear pump located at the lowest point of the oil reservoir pumps the oil through channels into the upper crankcase, from which there are leads to the crankshaft, which is drilled hollow in order to supply the oil direct under pressure to the main bearings, connecting rods, and timing gears. As the crankshaft revolves, the oil will gather in the motor pan, which is provided with ribs, and the connecting rods will dip in the oil and splash same around, thereby lubricating the pistons, piston pins, cam shafts and valve lifters. The surplus oil will run over the ribs and into the motor base and flow back to the reservoir, which is already mentioned, from where the oil is again pumped back into the system after being strained through the oil pump screen.

Every 2,000 miles the motor should be cleaned, drained, and new, fresh oil should be used after cleaning and draining the motor pan and oil leads. After the old oil is drained out, pour a gallon of kerosene through the regular combined filler and

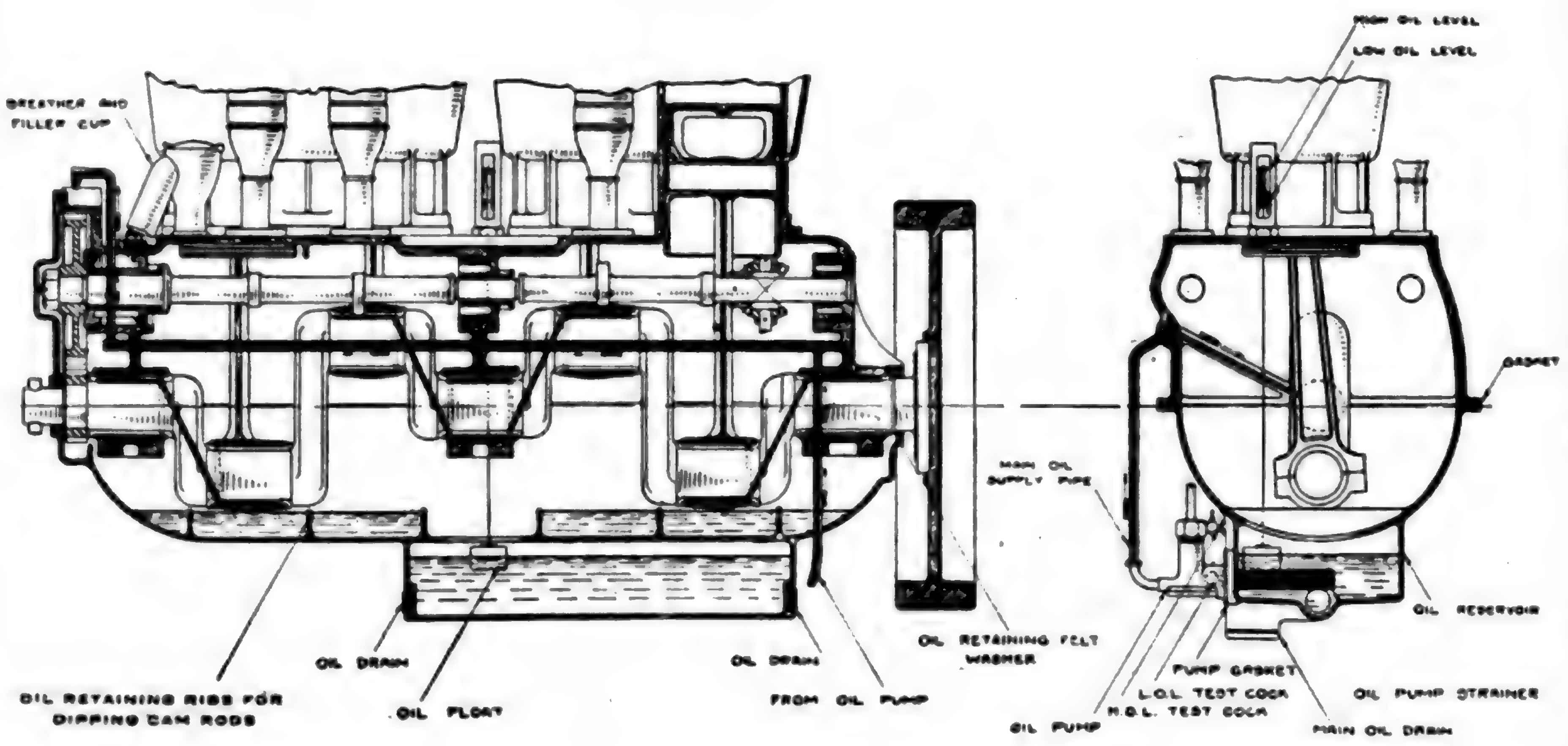

BREATHER AND FILLER CUP
HIGH OIL LEVEL
LOW OIL LEVEL
GASKET
MAIN OIL SUPPLY PIPE
OIL RESERVOIR
OIL RETAINING FELT WASHER
PUMP GASKET
L.O.L. TEST COCK
H.O.L. TEST COCK
OIL PUMP STRAINER
OIL PUMP
MAIN OIL DRAIN
OIL DRAIN
OIL DRAIN
FROM OIL PUMP
OIL RETAINING RIBS FOR DIPPING CAM RODS
OIL FLOAT

Fig. 129.—Sectional Views of Engine Used on Four-Wheel Drive Truck Which Brings Out Clearly Method of Lubrication Employed.

breather cap located at the front exhaust side; then run the motor for only a few seconds, drain same thoroughly, and refill with six quarts of fresh oil as specified. From time to time the oil pump should be removed and the screen should be cleaned. Make sure that all joints and pump packings are tight, and that the oil pump is running properly after replacing same.

This system used is the most positive and correct lubricating system for any motor, as proper lubrication is insured at all times under all possible conditions. The six quarts reserve oil are carried at the bottom of the crankcase, which has a float level connected with a gauge on the exhaust or left-hand side of the engine. This gauge has a high and low mark, and the bobber should never register below the low mark, but is supposed to be located between these two marks, or, better, near the highest mark. This should be looked after every day, making sure that the bobber has not become stuck, but is floating freely. The drain cocks and drain plugs should be inspected from time to time, as they may open and become loose and consequently would drain the oil.

Packard Motor Lubrication.—The oil is drawn through a screen from the crankcase oil reservoir and pumped into a pipe running to the oil screen and relief valve above the gear compartment, as shown at Fig. 130. The main outlet of this valve feeds through a lead in the crankcase web to the hollow camshaft, which acts as a distributing manifold. The camshaft is drilled at each bearing in line with oil grooves in the bearings, which lead through the crankcase webs to oil grooves in the main crankshaft bearings. The crankshaft is also drilled and carries oil from the main bearings to the lower connecting rod bearings. All bearings referred to are thus constantly flooded with oil under pressure, the surplus draining back to the crankcase reservoir. The cylinder walls are lubricated with oil spray thrown from the connecting rod bearings. The idler gearshaft is lubricated by force feed from the crankshaft through an oil lead encased in the crankcase. The overflow from the relief valve flows down and lubricates the front end gears. The magneto and water pump shafts are mounted on ball bearings which are lubricated by spray from the front end gears. The oil is strained before it enters the pump and again is strained before entering the camshaft. There is a sediment pocket in front of the oil pump. A baffle partition is located in the bottom of the crankcase to prevent surging of the oil in the oil reservoir. The clutch shaft forward bearing is packed in graphite grease.

A gear pump located at the lowest point of the crankcase draws oil through a strainer from the oil reservoir, circulating it through the main feed pipe, oil strainer and relief valve, to an oil duct in the crankcase leading to the camshaft which acts as an old manifold. The strainer may be removed from the oil pump housing without removing pump assembly by taking off the four nuts which hold the strainer cap in place. There is no

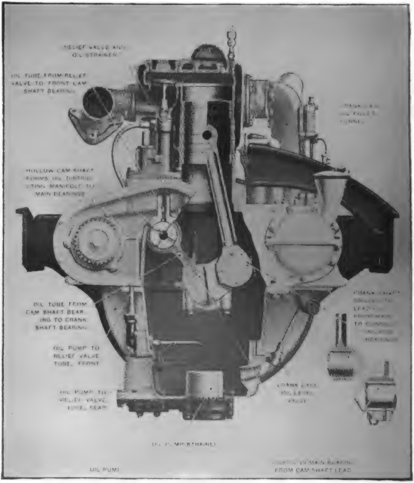

RELIEF VALVE AND OIL STRAINER
OIL TUBE FROM RELIEF VALVE TO FRONT CAM SHAFT BEARING
HOLLOW CAM SHAFT FORMS OIL DISTRIBUTING MANIFOLD TO MAIN BEARINGS
OIL TUBE FROM CAM SHAFT BEARING TO CRANK SHAFT BEARING
OIL PUMP TO RELIEF VALVE TUBE, FRONT
OIL PUMP TO RELIEF VALVE TUBE, REAR
OIL PUMP STRAINER
OIL PUMP
CRANK CASE OIL LEVEL VALVE
FROM CAM SHAFT LEAD

Fig. 130.—End Sectional View of Packard Motor Truck Engine Showing Lubrication System Parts.

adjustment to the oil pump. The pressure is regulated by means of the relief valve. The pump is operated by a shaft, driven by helical gears on the camshaft. The pump may be removed for cleaning or inspection by removing the nuts which hold it to the bottom of the crankcase.

There is a strainer in the bottom of the crankcase reservoir, as outlined at Fig. 131, which covers the entrance to the oil pump. The oil is thus strained before it enters the pump. Before it enters the camshaft for distribution the oil passes through a basket strainer in the relief valve housing at the front of the motor. If the oil pressure drops below normal when crankcase oil supply is up to level, drain the oil from the crankcase through the crankcase drain plugs and remove and clean both strainers. The oil pump strainer may be removed easily by removing the nuts from the four studs which fasten the strainer cap to the pump body. To remove relief valve strainer, unscrew the cover and lift strainer out. There is a gauge on the dashboard which shows the oil pressure. On a new or overhauled motor the normal running pressure is 4 to 6 pounds at 1,075 r.p.m., maximum speed, controlled by the governor with the motor warm. After the truck has been run about 750 miles the pressure should be set to three pounds with the motor warm.

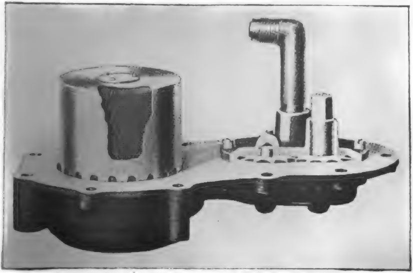


Fig. 131.—Wire Screen Oil Filter and Gear Pump Used on Packard Engines.

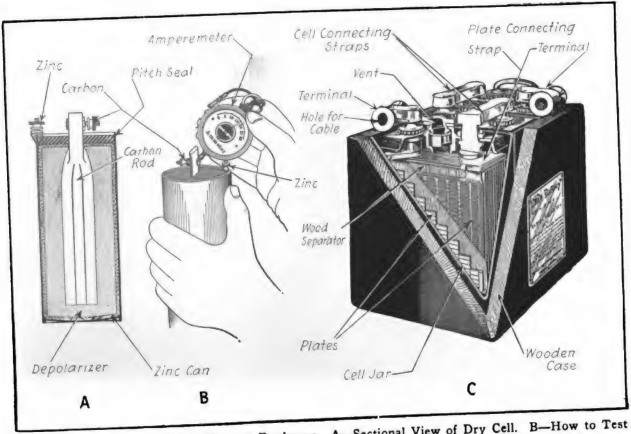

Zinc
Carbon
Pitch Seal
Carbon Rod
Depolarizer
Zinc Can
A
Amperemeter
Zinc
B
Cell Connecting Straps
Vent
Terminal
Hole for Cable
Wood Separator
Plates
Cell Jar
Plate Connecting Strap
Terminal
Wooden Case
C

Fig. 132.—Comparing Chemical Current Producers. A—Sectional View of Dry Cell. B—How to Test C—Part Sectional View of Storage Battery Used for Automobile Ignition,

CHAPTER V

THE MOTOR TRUCK ELECTRICAL SYSTEM

Chemical Current Producers—Wiring Dry Cells—Storage Battery Construction—Essential Elements of Simple Ignition System—Non-Vibrator Distributor Systems—Delco and Remy Distinctive Ford System—Spark Plug Construction—Magneto Construction—Magneto Ignition Systems—The Dixie Magneto—Timing Magneto Ignition System—Impulse Starters—Dual Magneto Systems—Duplex Systems—Self-Starters for Gasoline Engines—Electric Starting Systems—Starting System Parts—Motors and Dynamos—Governor Action—Function of Amperemeter.

The electrical system of the modern motor truck may be divided into three distinct groups, each for a specific purpose. The most important is the ignition system which produces the sparks in the engine cylinders to ignite the gasoline vapor and air mixture to produce power, as fully explained in the chapter on engine action. This includes timing devices, current production apparatus, distributing mechanism, induction coil, wiring and spark plugs. The lighting system is very simple, comprising lamps, wiring and switches necessary for their control. The same battery used for the starting system is used to supply lighting current.

The electrical starting group, if electrical energy is used for that purpose, consists of a high capacity storage battery, an electric motor to turn the engine over in lieu of the hand crank, a current generator or dynamo driven by the engine to keep the battery charged, and various current controlling and regulating devices to be fully described in connection with the exposition on starting and lighting systems at the close of this chapter.

Chemical Current Producers.—A simple form of current producer of this nature is depicted in section at Fig. 132, A. This is known as a dry cell and consists of a zinc can in the center of which a carbon rod is placed. The electrolyte is held close to the zinc or negative member by an absorbent lining of blotting paper, and the carbon rod is surrounded by some depolarizing material. The top of the cell is sealed with pitch to prevent loss of depolarizer.

The depolarizer is needed that the cell may continue to generate current. When the circuit of a simple cell is completed the current generation is brisker than after the cell has been producing electricity for a time. While the cell has been in action the positive element becomes covered with bubbles of hydrogen gas, which is a poor conductor of electricity and tends to decrease the current output of the cell. To prevent these bubbles from interfering with current generation some means must be provided for disposing of the gas. In dry cells the hydrogen gas that causes polarization is combined with oxygen gas evolved by the depolarizing medium, and the combination of these two gases produces water, which does not interfere with the action of the cell. Carbon is used in a dry cell instead of copper, because it is a cheaper material and the electrolyte is a mixture of sal ammoniac and chloride of zinc which is held in intimate contact with the zinc shell which forms the negative element by the blotting-paper lining.

A single dry cell will not produce sufficient current to ignite the charge of gas in the engine cylinder, therefore it is common practice to combine two or more cells in such a manner that batteries are formed which will give more current than a single cell.

Wiring Dry Cells.—If one dry cell will produce one and one-half volts and six volts are needed to produce the spark in the engine cylinder, the current value of one dry cell is augmented by coupling three others to it in a series connection. When cells are connected in series it is the unlike elements which are joined together. For example, the zinc of one cell should be joined with the carbon of the adjacent member by a flexible conductor. This will leave the carbon of one end cell and the zinc of the other end cell free to be placed into the circuit. As dry cells become exhausted they must be replaced with new ones periodically. A storage battery can be charged from external sources and maintained in good condition for extended periods, so this type of battery is usually used for starting, lighting and ignition work on passenger cars and trucks.

Storage Battery Construction.—When storage cells are to be used in motor truck work they are combined in a single containing member, as shown at Fig. 132, C, which is a part sectional view of a storage battery used for ignition purposes. The main containing member, a jar of hard rubber, is divided into three parts. Each of these compartments serves to hold the elements comprising one cell. The positive and negative plates are spaced apart by wood and hard rubber separators which prevent short circuiting between the plates. After the elements have been put in place in the compartments forming the individual cells of the battery, the top of the jar is sealed by pouring a compound of pitch and rosin, or asphaltum, over plates of hard rubber, which keeps the sealing material from running into the cells and on the plates. Vents are provided over each cell through which gases produced by charging or discharging are allowed to escape. These are so formed that while free passage of gas is provided for, it is not possible for the electrolyte to splash out when the vehicle is in motion.

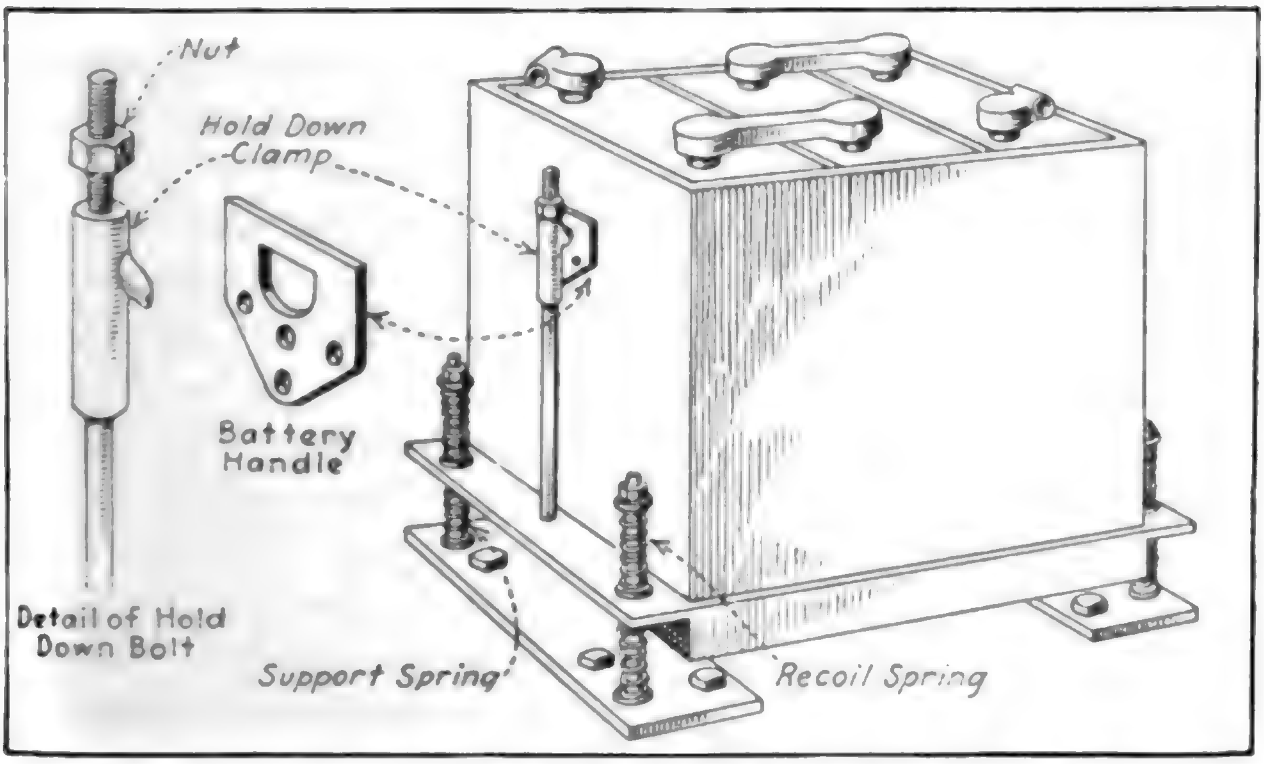


Fig. 133.—Diagram Showing Method of Mounting Storage Battery and Shock Absorbing Springs So It Will Not Be Damaged by Vibration of Motor Truck Chassis.

It will be evident that this method of sealing would not be practical on a cell where the members attacked by the acid had to be replaced from time to time, but in a storage battery only the electrolyte need be renewed. When the plates are discharged they are regenerated by passing a current of electricity through them. New electrolyte can be easily inserted through caps in which the vents are screwed. The cells of which a storage battery is composed are joined together at the factory with bars of lead which are burned in place and only two free terminals are provided by which the battery is coupled to the outer circuit.

A spring battery mounting for storage battery installation on trucks, whereby shocks to the battery are greatly decreased, promoting the life of the battery, is shown at Fig. 133. Briefly, the battery rests on a metal tray that is suspended between four coiled steel springs that are bolted to the truck body, or running board. These frames are $\frac{1}{8}$-inch steel wire wound to $\frac{13}{16}$ inch diameter, the lower one being $2\frac{3}{4}$ inches long and the upper one 2 inches long, and the tension on them may be adjusted by nuts at the top of the supporting bolts. The tray is malleable iron and the battery is held firmly in it by means of hold-downs clamped in the battery handle.

Essential Elements of Simple Ignition System.—The current obtained from the dry or storage battery or low-tension dynamo or magneto is not sufficiently powerful to leap the gap which exists between the points of the spark plug in the cylinder unless it is transformed to a current having a higher potential. The air gap between the points of the spark plug has a resistance which requires several thousand volts pressure to overcome, and as a battery will only deliver six to eight volts, it will be evident that, unless the current value is increased, it could not produce a spark between the plug electrodes.

The low voltage current is transformed to one of higher potential by means of a device known as the induction coil. The current from the battery is passed through the primary coil, which is composed of several layers of coarse wire wound around a core of soft iron wire to form an electro-magnet. Surrounding this primary coil is one composed of a large number of turns of finer conductor. When a current of electricity of low voltage passes through the primary coil, a current of very high electromotive force is produced in the secondary winding. One end of each coil is grounded. The free end of the primary coil is coupled to the battery while that of the secondary coil is attached to the insulated terminal of the distributor that directs the electric current to the spark plugs.

Non-vibrator Coil and Distributor Systems.—Because of the almost universal employment of electricity for lighting and starting systems, the battery ignition system has been improved materially inasmuch as the storage battery supplying the current is now constantly charged by a generator. A number of systems has been devised, these operating on two different principles, the open and the closed circuit. Several typical complete

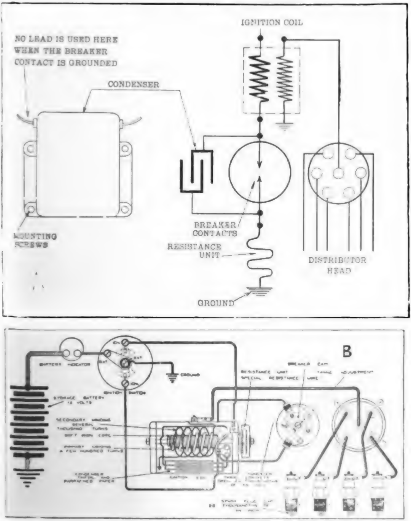

IGNITION COIL
NO LEAD IS USED HERE WHEN THE BREAKER CONTACT IS GROUNDED
CONDENSER
MOUNTING SCREWS
BREAKER CONTACTS
RESISTANCE UNIT
DISTRIBUTOR HEAD
GROUND
B
BATTERY INDICATOR
GROUND
IGNITION SWITCH
STORAGE BATTERY 12 VOLTS
SECONDARY WINDING SEVERAL THOUSAND TURNS
SOFT IRON CORE
PRIMARY WINDING A FEW HUNDRED TURNS
CONDENSER TINFOIL AND PARAFFINED PAPER
BREAKER CAM
RESISTANCE UNIT SPECIAL RESISTANCE WIRE
TIMING ADJUSTMENT

Fig. 134.—Simplified Wiring Diagram at A Shows Parts of Delco Ignition System. The Complete Wiring Diagram at B Shows the Delco Ignition System as It is Actually Applied to a Four-Cylinder Engine.

electrical systems, including ignition, starting and lighting circuits, are shown in connection with explanatory matter on these systems. The storage battery is kept properly charged by the motor-generator unit.

The action of the Delco system, shown at Fig. 134, A and B, is very much the same as that of any battery non-vibrator coil outfit. The simplified diagram shows the relation of the coil, condenser, primary timer and secondary distributor head. The

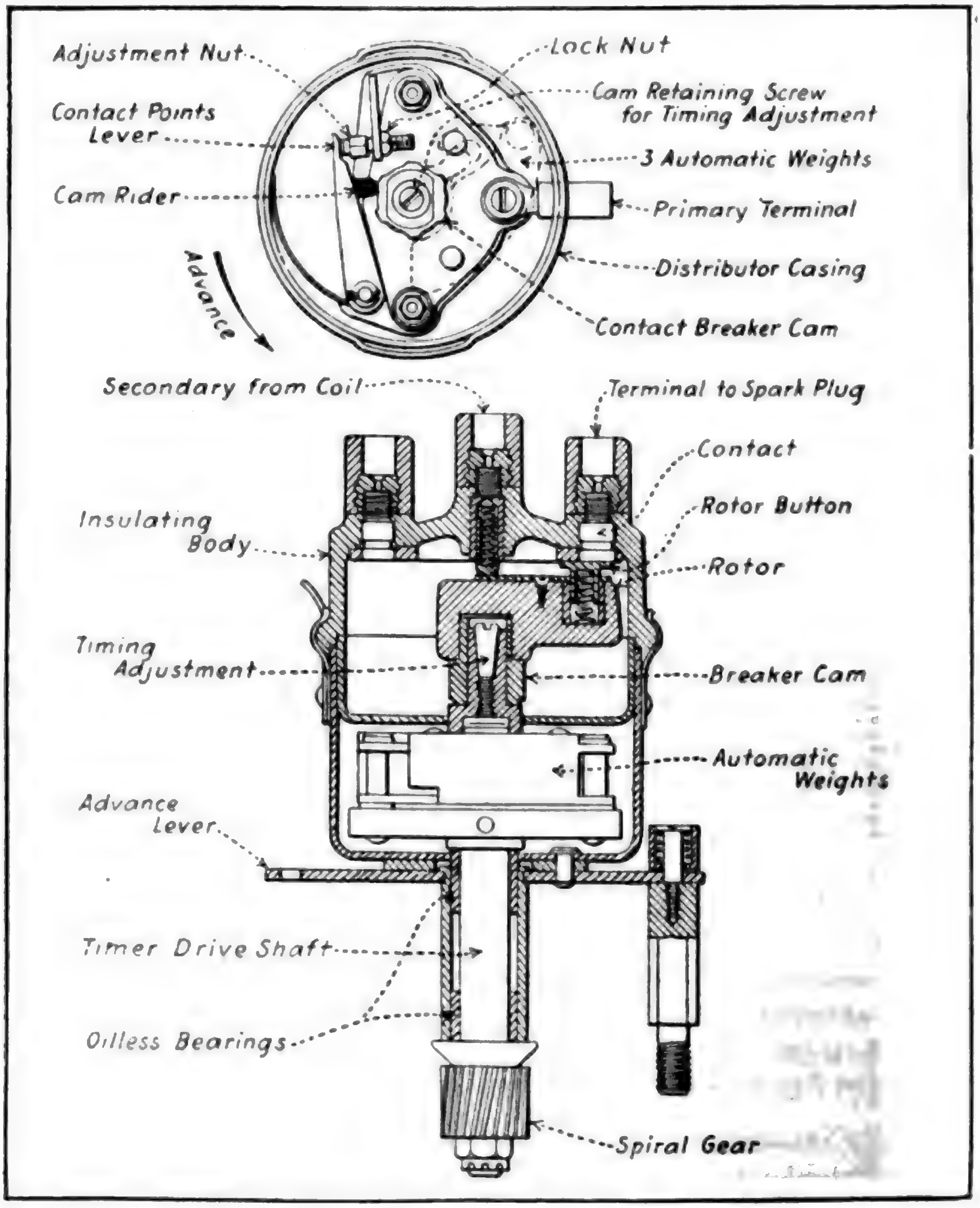

Adjustment Nut
Lock Nut
Cam Retaining Screw for Timing Adjustment
Contact Points Lever
3 Automatic Weights
Cam Rider
Primary Terminal
Advance
Distributor Casing
Contact Breaker Cam
Secondary from Coil
Terminal to Spark Plug
Contact
Rotor Button
Insulating Body
Rotor
Timing Adjustment
Breaker Cam
Automatic Weights
Advance Lever
Timer Drive Shaft
Oilless Bearings
Spiral Gear

Fig. 135.—The Delco Timer Distributor with Simple Automatic Spark Advance.

battery is not shown connected, but one terminal is grounded, the wire from the other passes through a switch and to the primary lead of the ignition coil. One end of the secondary coil is grounded, the other secondary lead conducts the high-tension current to the central distributor terminal. The other distributor terminals are connected to the spark plugs. The primary circuit includes the coarse wire winding of the ignition coil, the battery and the timer contacts. The condenser is in shunt and no primary current can pass through it.

The ignition system is composed of a combined timer and distributor, as shown at Fig. 135, and a coil for delivering a high-tension spark to the distributor. The distributor consists of a cap or head of insulating material carrying a high-tension distributing contact in the center, while four similar collecting contacts are spaced equi-distant about the center one, when device is used on a four-cylinder motor. A rotor member directs the current from the center contact to that leading to the plug in the cylinder about to fire. The timer portion of the ignition unit is a short contact platinum point form having a cam with as many points as there are cylinders to be ignited and terminals on the distributor head. The device shown is for six-cylinder engine ignition, so the cam has six humps on its periphery. It sends a current of electricity through the primary winding of the induction coil each time that a spark is needed in the engine. In place of the fuses which are used on some systems a protective circuit breaker is attached to the switch panel (see Delco Starting System) which gives warning of a short circuit by rapidly vibrating an armature. The various parts of the system and all of the circuits are clearly shown in the diagram, and in view of what has been previously said, no difficulty should be experienced in tracing the various wires.

Battery ignition systems are becoming so popular that some of these are arranged on a special base that will fit the standard size platforms used for holding magnetos. The wiring diagram of a Remy conversion set of this type and the appearance of the ignition unit which includes coil, timer and driving gears, is shown at Fig. 136. All parts are clearly designated, and the reader should have no difficulty in identifying them.

Distinctive Ford System.—The Ford car has a magneto system and can also use batteries. The timer has four segments, a separate coil being provided for each cylinder. The simplified wiring diagram is shown at Fig. 137, the system as applied to the engine at Fig. 138. The Ford is the only engine using the system of ignition shown in these two cuts.

Spark Plug Construction.—With the high-tension system of ignition the spark is produced by a current of high-voltage jump-

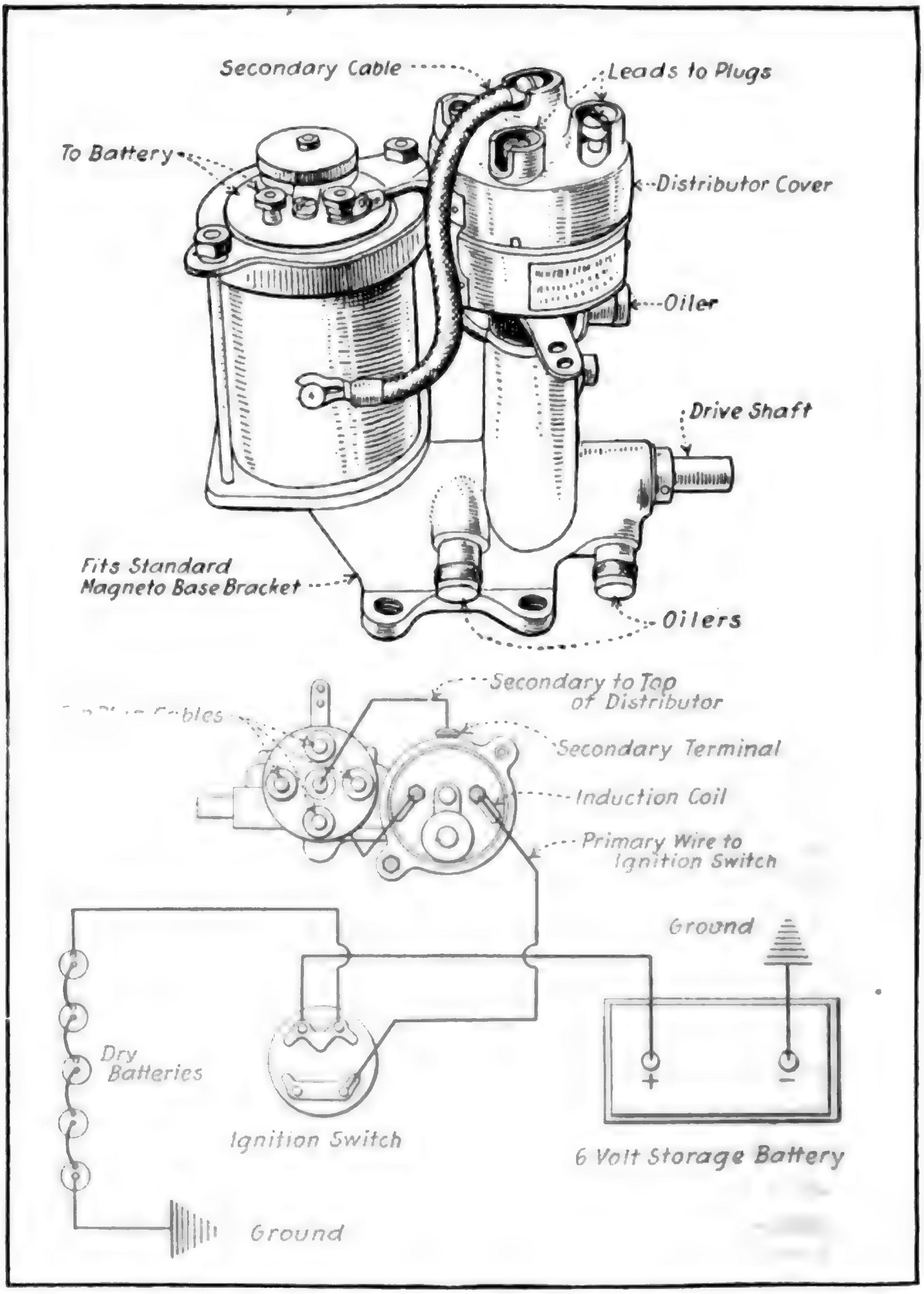

Secondary Cable
Leads to Plugs
To Battery
Distributor Cover
Oiler
Drive Shaft
Fits Standard Magneto Base Bracket
Oilers
Secondary to Top of Distributor
Spark Plug Cables
Secondary Terminal
Induction Coil
Primary Wire to Ignition Switch
Ground
Dry Batteries
+
−
Ignition Switch
6 Volt Storage Battery
Ground

Fig. 136.—Remy Ignition Outfit for Attachment to Magneto Base Engine Crank Case.

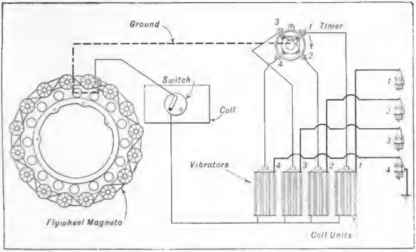

Ground
3
1 Timer
2
4
Switch
Coil
1
2
3
4
Vibrators
4
3
2
1
Flywheel Magneto
Coil Units

Fig. 137.—Unconventional Transformer Coil-Magneto Ignition System Used on Ford Cars in Diagram Form.

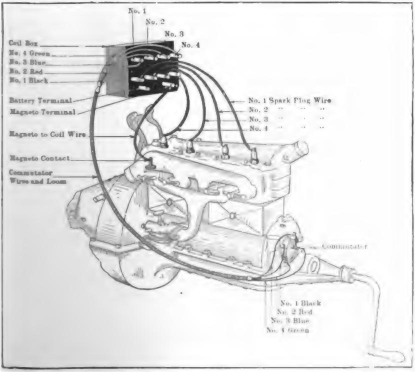

No. 1
No. 2
No. 3
No. 4
Coil Box
No. 4 Green
No. 3 Blue
No. 2 Red
No. 1 Black
Battery Terminal
Magneto Terminal
Magneto to Coil Wire
Magneto Contact
Commutator Wires and Loom
No. 1 Spark Plug Wire
No. 2 " " "
No. 3 " " "
No. 4 " " "
Commutator
No. 1 Black
No. 2 Red
No. 3 Blue
No. 4 Green

Fig. 138.—The Complete Ford Magneto Ignition System, a Distinctive Method Found Only on This Car.

ing between two points which break the complete circuit, which would exist otherwise in the secondary coil and its external connections. The spark plug is a simple device which consists of two terminal electrodes carried in a suitable shell member, which is screwed into the cylinder. Typical spark plugs are shown in section at Fig. 139 and the construction can be easily understood. The secondary wire from the coil is attached to a terminal at the top of a central electrode member, which is supported in a bushing of some form of insulating material. The type shown at A employs a molded porcelain as an insulator, while that depicted at B uses a bushing of mica. The insulating bushing and electrode are housed in a steel body, which is provided with a screw thread at the bottom, by which it is screwed into the combustion chamber.

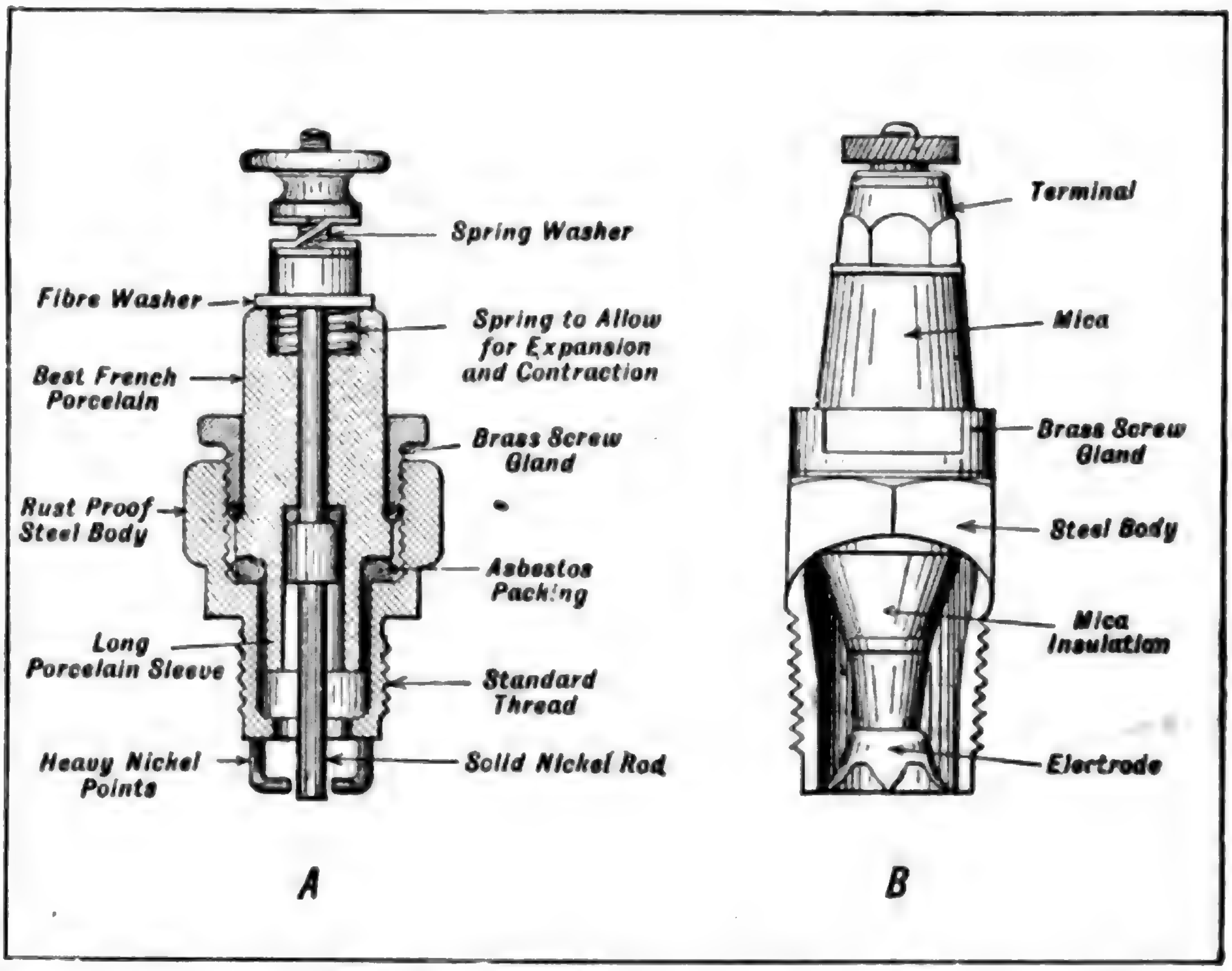

Spring Washer
Fibre Washer
Spring to Allow for Expansion and Contraction
Best French Porcelain
Brass Screw Gland
Rust Proof Steel Body
Asbestos Packing
Long Porcelain Sleeve
Standard Thread
Heavy Nickel Points
Solid Nickel Rod
A
Terminal
Mica
Brass Screw Gland
Steel Body
Mica Insulation
Electrode
B

Fig. 139.—Spark Plug Construction Outlined. A—Sectional View of Porcelain Plug. B—Part Sectional View of Mica Plug.

When porcelain is used as an insulating material it is kept from direct contact with the metal portion by some form of yielding packing, usually asbestos. This is necessary because the steel and porcelain have different coefficients of expansion and some flexibility must be provided at the joints to permit the materials to expand differently when heated. The steel body of the plug which is screwed into the cylinder is in metallic contact with it and carries sparking points which form one of the terminals of the air gap over which the spark occurs. The current entering at the top of the plug cannot reach the ground, which is represented by the metal portion of the engine, until it has traversed the full length of the central electrode and overcome the resistance of the gap between it and the terminal point on the shell. The porcelain bushing is firmly seated against the asbestos packing by means of a brass screw gland which sets against a flange formed on the porcelain, and which screws into a thread at the upper portion of the plug body.

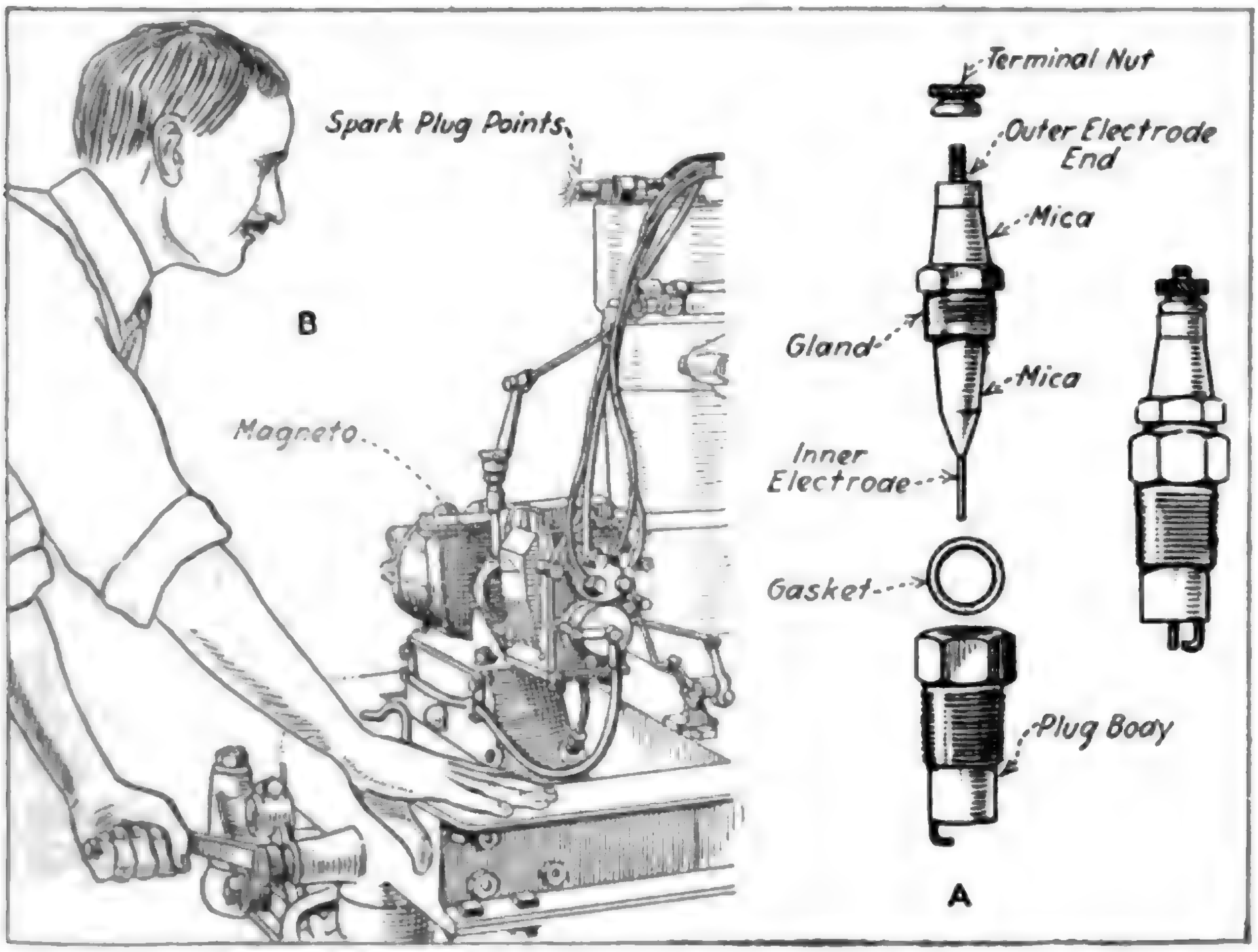


Fig. 140.—Showing Method of Testing Spark Plug and How Spark Plug Looks When It is Dismantled.

The mica plug shown at B is somewhat simpler in construction than that shown at A. The mica core which keeps the central electrode separated from the steel body is composed of several layers of pure sheet mica wound around the steel rod longitudinally, and hundreds of stamped mica washers which are forced over this member and then turned down smooth in a lathe. Lava and glass have also been used as insulation, but the porcelain insulated plug is the most popular.

The parts comprising a typical spark plug are shown at Fig. 140, A, and the method of testing a plug to make sure a spark jumps between the points as the engine is cranked over is shown at B.

Magneto Construction.—The magneto is a simple form of dynamo and a mechanical generator of electricity in which per-

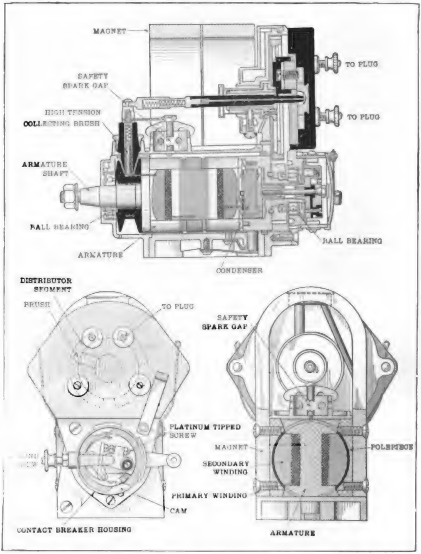

MAGNET
TO PLUG
SAFETY SPARK GAP
HIGH TENSION COLLECTING BRUSH
TO PLUG
ARMATURE SHAFT
BALL BEARING
BALL BEARING
ARMATURE
CONDENSER
DISTRIBUTOR SEGMENT
BRUSH
TO PLUG
SAFETY SPARK GAP
PLATINUM TIPPED SCREW
MAGNET
POLEPIECE
SECONDARY WINDING
PRIMARY WINDING
CAM
CONTACT BREAKER HOUSING
ARMATURE

Fig. 141.—View Showing Internal Construction of Bosch D. U. 4 High-Tension Magneto.

manent magnets are used to produce the magnetic field and between which the armature revolves. The permanent magnets are called "field magnets" and at their ends are provided cast-iron shoes which form the walls of the armature tunnel and which are known as pole pieces. A typical magneto adapted for four-cylinder ignition is shown in section at Fig. 141. It consists of two compound horseshoe magnets attached to the pole pieces which collect and concentrate the magnetism upon the armature. The armature is shuttle-shaped and carries a double winding of wire which consists of two coils, one of coarse, the other of fine conductor. The armature is attached to end pieces which carry shafts and the whole assembly revolves on annular ball bearings. An ebonite or hard rubber spool is carried at one end, while the condenser is housed at the other. The make-and-break mechanism is partly carried by an oscillating casing and the revolving member is turned from the armature shaft.

The current generated in the coil is delivered to a metal ring on the ebonite spool, from which it is taken by a carbon brush and delivered to the distributor, from which member a series of contact segments lead directly to the spark plugs. Every time the contact points in the make-and-break devices become separated, a current of high potential passes through the wires attached to the spark plug and produces a spark between the points. The magneto is the simplest and most practical form of ignition appliance, as it is self-contained and includes the current generator and the timing device in one unit.

A magneto employed for multiple-cylinder ignition is not much more complicated than that used for single-cylinder service, the only difference being that a different form of cam is provided in the breaker box and that a secondary distributor is added to commutate the current to the plugs in the various cylinders. The distributor consists of a block of insulating material fixed to the magnets which carries as many segments as there are cylinders to be fired. A central distributing arm or segment is driven from the armature shaft by means of gearing, and is employed to distribute the high-tension current to the spark plug. The spacing of the distributor segments does not differ materially from that of the battery timers. If the distributor is used on a four-cylinder motor the segments are spaced 90 degrees apart. To fire a six-cylinder motor, six segments must be used, and they are placed 60 degrees apart. The speed

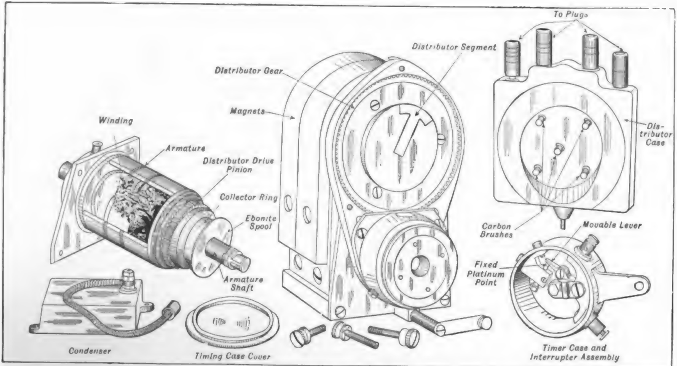

To Plugs
Distributor Segment
Distributor Gear
Magnets
Winding
Armature
Distributor Drive Pinion
Collector Ring
Ebonite Spool
Armature Shaft
Dis-tributor Case
Carbon Brushes
Movable Lever
Fixed Platinum Point
Condenser
Timing Case Cover
Timer Case and Interrupter Assembly

Fig. 142.—Partially Dismantled Four-Cylinder Magneto Showing Important Parts of Current Producing and Distributing Elements.

at which the armature of the magneto turns also varies with the number of cylinders. One-and-two cylinder forms turn at camshaft speed. The four-cylinder magneto is driven at crankshaft speed, while that of the six-cylinder forms turn at 1½ times crankshaft speed.

The important parts of a four-cylinder form of high-tension magneto are shown at Fig. 142, which is a view of a partially

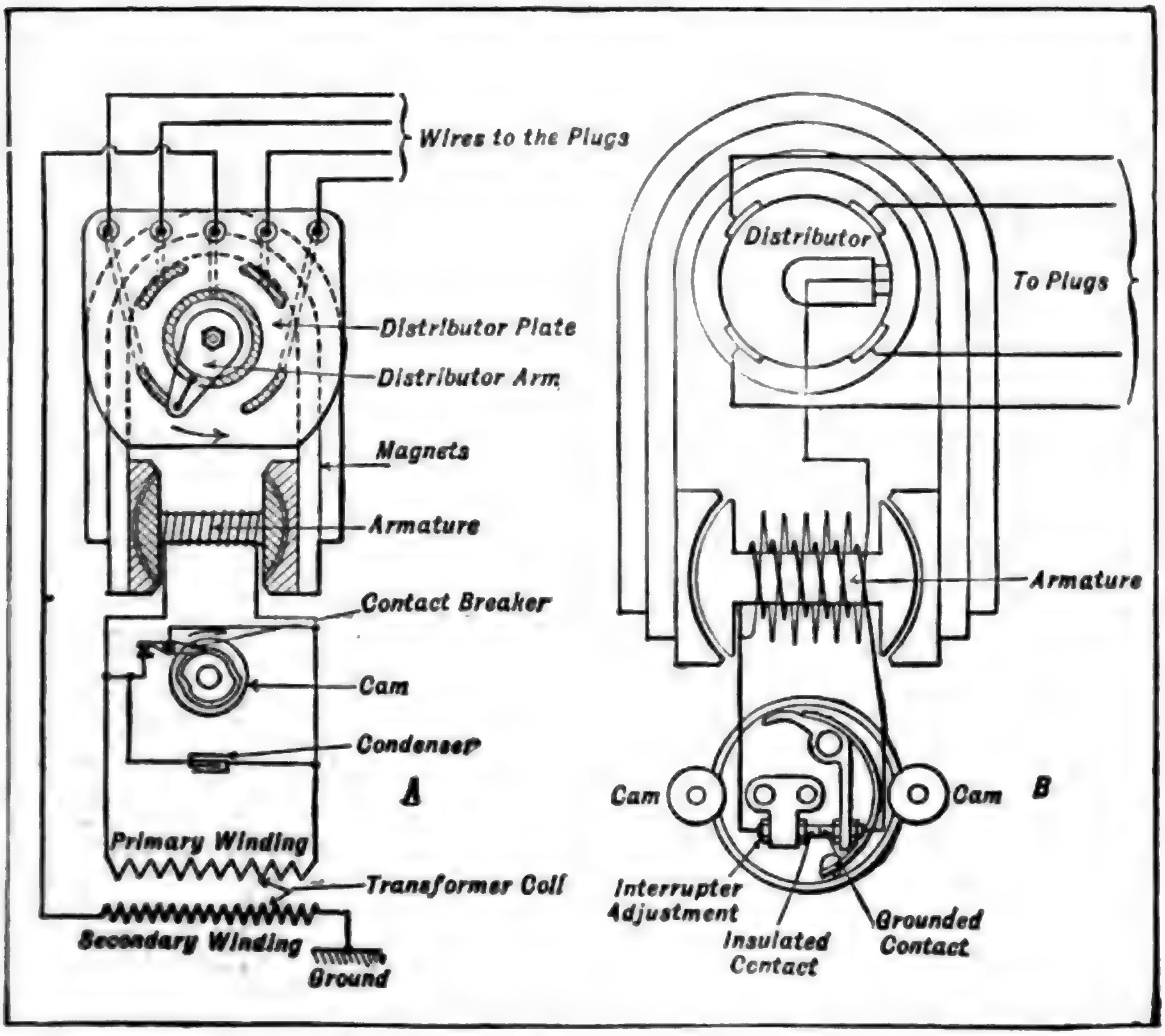

Wires to the Plugs
Distributor Plate
Distributor Arm
Magnets
Armature
Contact Breaker
Cam
Condenser
A
Primary Winding
Transformer Coil
Secondary Winding
Ground
Distributor
To Plugs
Armature
Cam
Cam
B
Interrupter Adjustment
Insulated Contact
Grounded Contact

Fig. 143.—Diagrams Explaining Action of Low-Tension of Transformer Coil Magneto System at A, and True High-Tension Magneto System at B.

dismantled device. The armature assembly and one of the end plates by which it is supported are shown at the extreme left. Attached to the end of the armature shaft are the distributor drive pinion and the ebonite spool which carries the collector ring. The timer case and interrupter assembly are shown at the extreme right. Above it the distributor case is clearly depicted. When the device is assembled the end of the armature shaft protrudes through the housing at the lower part of the magnet assembly, which is shown in the center of the group, with the end plate which carries the distributor gear and disc and one end of the armature in place. The distributor gear serves to drive a hard rubber plate in which the distributor segment is imbedded. When the distributor case is screwed in place, the carbon brushes, which are spaced around the interior of the distributor case, collect current from the revolving distributor segment and lead it to the spark plugs by suitable cables which run from the terminals at the top of the distributing casing.

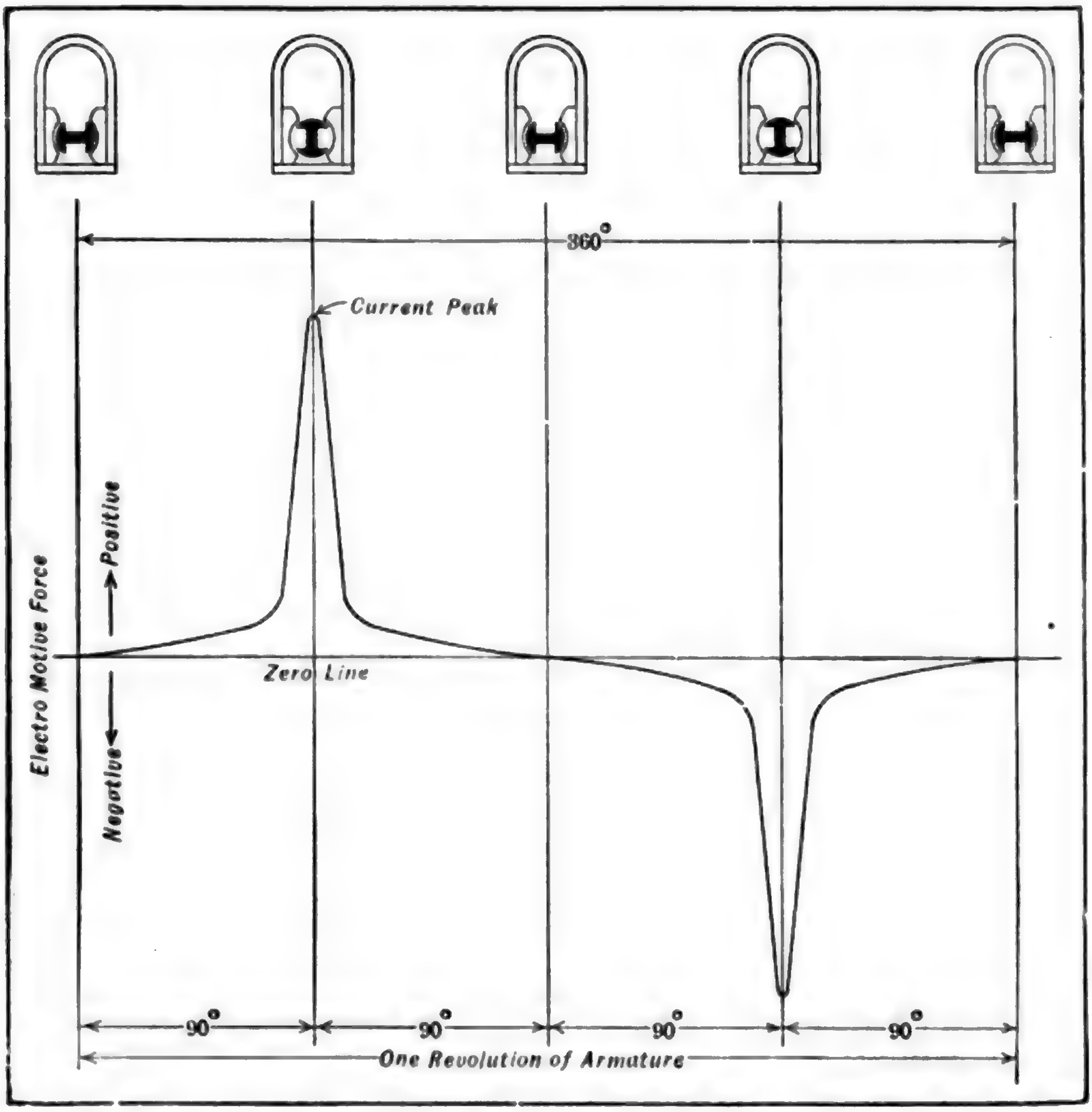


Fig. 144.—Diagram Explaining How Magneto Current Strength Fluctuates with Varying Armature Positions.

Magneto Ignition Systems.—Two systems of high-tension magneto ignition are used, one termed the true high-tension system, in which a current of high potential is delivered directly from the armature, as at Fig. 143, B; the other is the transformer coil system and is shown at Fig. 143, A, so termed because the

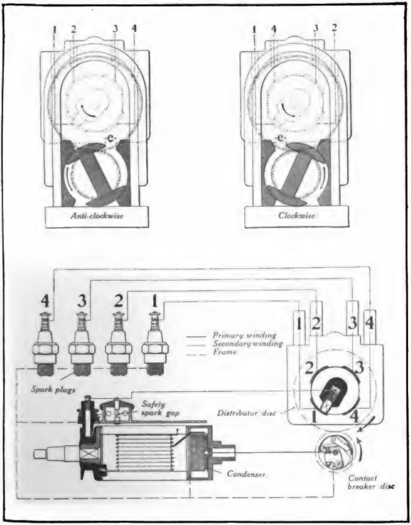

1 2 3 4
1 4 3 2
e
e
Anti-clockwise
Clockwise
4
3
2
1
1 2 3 4
Primary winding
Secondary winding
Frame
2
3
1
4
Spark plugs
Safety spark gap
Distributor disc
Condenser
Contact breaker disc

Fig. 145.—Simplified Wiring Diagram Showing Action of Bosch High-Tension Magneto.

current produced by the armature winding is of low tension and must be stepped up or increased in value before it is delivered to the spark plug by an induction coil similar in construction to that needed in battery-ignition systems. In the former apparatus the high-tension current is produced by means of a secondary winding on the armature itself, and as the whole apparatus is self-contained, it is compact and simpler to install than those which need a separate transformer coil.

The simplified wiring system of a true high-tension magneto is shown at Fig. 145. The armature carries two windings, one indicated by the heavier lines at the bottom called the "primary"; the other, composed of finer conductor, is known as the "secondary." One end of the primary winding is grounded; the other is joined to the fixed contact screw on the contact breaker. This end is also joined to one end of the secondary winding and the free end of the secondary winding is attached to the collector ring carried by the ebonite spool. When the contact points separate, a current is induced in the primary and secondary windings and is delivered to the center terminal of the distributor disc by the carbon brush which bears against the collector ring. The various segments of the distributor are connected to the spark plugs in the cylinders and the current is delivered to the plug about to fire at the proper time. The parts of a typical transformer coil-magneto system are shown at Fig. 146.

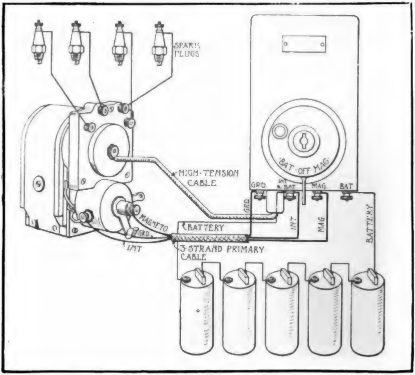

SPARK PLUGS
HIGH-TENSION CABLE
BAT·OFF·MAG
GRD
INT & BAT
MAG
BAT
GRD
INT
MAG
BATTERY
MAGNETO
GRD.
INT
BATTERY
3-STRAND PRIMARY CABLE

Fig. 146.—Typical Transformer Coil Magneto System for Four-Cylinder Ignition.

The Dixie Magneto.—This efficient ignition device differs from the conventional type because it has a rotary inductor and a stationary winding. This inductor member consists of two revolving wings made of steel and separated from each other by a bronze centerpiece. These wings are attached firmly to the shaft and revolve with it. The wings are plainly shown in Fig. 149.

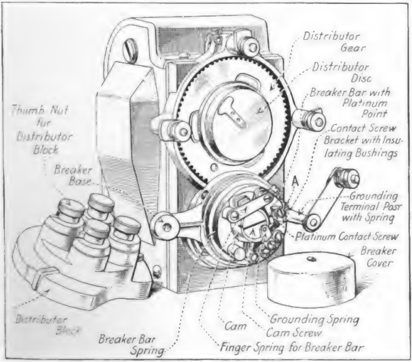

Distributor Gear
Distributor Disc
Breaker Bar with Platinum Point
Thumb Nut for Distributor Block
Contact Screw
Bracket with Insulating Bushings
Breaker Base
A
Grounding Terminal Post with Spring
A
Platinum Contact Screw
Breaker Cover
Distributor Block
Breaker Bar Spring
Cam
Grounding Spring
Cam Screw
Finger Spring for Breaker Bar

Fig. 147.—Parts of Dixie Four-Cylinder Magneto.

In addition to the main rotating member, the Dixie magneto has two poles of soft laminated iron, or made up of a number of sheets of iron. These poles are connected by a piece of soft iron upon which are wound the two coils of wire. The lower part of the poles is shaped in the form of a half circle, and the two revolving wings as they turn come within a very few thousandths of an inch of these poles. The ends of the revolving wings just barely clear the ends of the permanent magnets; that is, one revolving wing almost touches one set of poles of the permanent magnets, while the opposite wing almost touches the opposite poles of the permanent magnets.

Now let us see how current is generated in the machine, and how the rule as to lines of force works out. If the reader will refer to Fig. 149, he will notice a number of small arrows which indicate the direction of the lines of magnetic force. The rotating member is turned so that one of the revolving wings is just beneath the laminated iron pole. In this position the magnetic lines of force or magnetism, as it is termed, travels from the steel magnet through one of the wings on the rotating member to the laminated iron pole, through the pole, through the center of coil to the other pole, thence across the opposite pole of the steel magnet. This action induces a current in the windings of the coil and so generates a spark. This action has been explained in connection with the action of the conventional rotary winding type magneto.

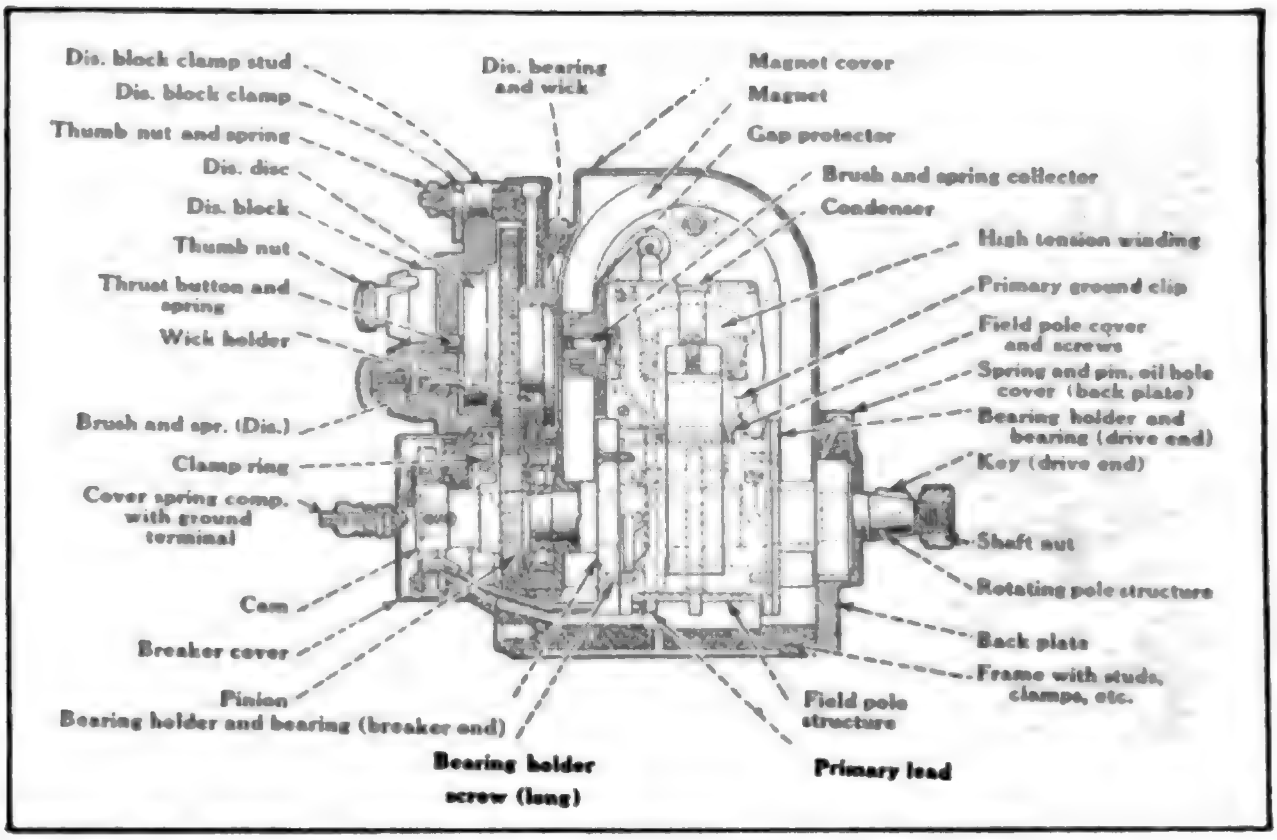

Dis. block clamp stud
Dis. block clamp
Thumb nut and spring
Dis. disc
Dis. block
Thumb nut
Thrust button and spring
Wick holder
Brush and spr. (Dis.)
Clamp ring
Cover spring comp. with ground terminal
Cam
Breaker cover
Pinion
Bearing holder and bearing (breaker end)
Bearing holder screw (long)
Dis. bearing and wick
Magnet cover
Magnet
Gap protector
Brush and spring collector
Condenser
High tension winding
Primary ground clip
Field pole cover and screws
Spring and pin, oil hole cover (back plate)
Bearing holder and bearing (drive end)
Key (drive end)
Shaft nut
Rotating pole structure
Back plate
Frame with studs, clamps, etc.
Field pole structure
Primary lead

Fig. 148.—Longitudinal Part Sectional View of the Dixie Magneto.

As the rotating member is turned one-half of a revolution, the lines of force travel through the wings, but in the opposite direction. This action can be seen perhaps more clearly by reference to Fig. 149. At A is shown an end view of the machine. Bear in mind that the revolving wing N almost touches the north pole of the steel magnets, while S almost touches the south poles of the magnets. There is quite a considerable gap, however, between the revolving wing N and the south pole of the steel magnets. In this case, the magnetic lines have traveled from the north pole of the steel magnets to the center of the machine, where the coil and iron magnets are located. The small arrows show the path or the lines of force.

You will note that in this case the magnetic lines pass through the coil windings on No. 5 from the left toward the right. Now refer to C in the same figure. The rotating member has traveled one-quarter of its way around. The lines of force, instead of traveling through the soft iron magnet on the left side, are now diverted to the right hand pole No. 4. Therefore the magnetic

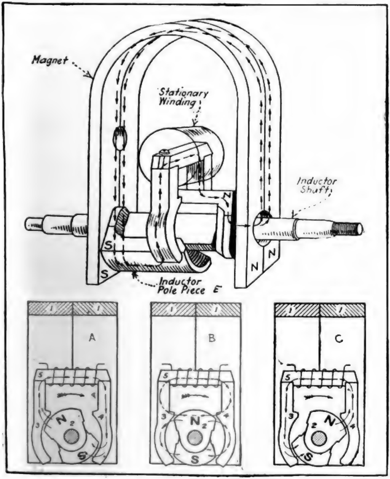

Magnet
Stationary Winding
Inductor Shaft
N
S
Inductor Pole Piece E
1
A
B
C
S
N
2
3
4

Fig. 149.—Diagrams Showing How the Dixie Rotary Inductor Magneto Operates.

lines travel through the core from the right to the left. This change in the direction of the lines therefore occurs twice in every revolution of the revolving member.

There is another peculiar fact about magnetism. A piece of steel holds magnetism for a long time, and when it is magnetized usually we term it a permanent magnet. A piece of soft iron, on the other hand, loses its magnetism very quickly. Obviously, for the poles No. 3 and No. 4, soft iron should be used. If instead of using a solid piece of soft iron a number of thin sheets are used the magnetism is lost more quickly even than when solid iron is used. For that reason the poles and the center core No. 5 are made up of many sheets of soft iron.

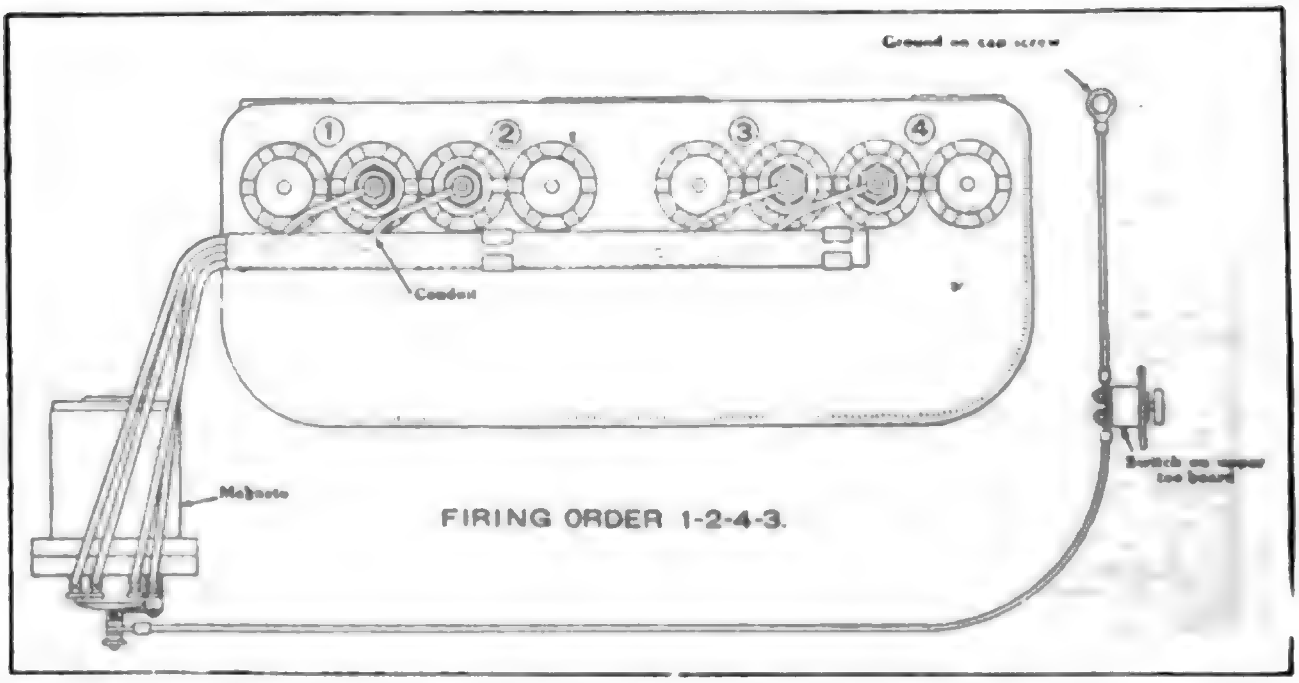


Fig. 150.—Diagram Showing Simple Wiring with High-Tension Magneto as Used for Ignition.

In order to assist the demagnetizing of the center core, the machine is so designated that the rotating wings N and S at one period of their rotation, as shown at B in Fig. 149, short-circuit the magnetic lines. The slight amount of magnetism that is in the soft iron poles discharges itself through the rotating wings. The coil of wire is nothing more or less than a small spark coil. It consists of a number of turns of coarse wire as a primary and a large number of turns of fine wire on the outside as a secondary. One end of the fine wire is grounded to the base of the machine, while the other end is connected with the center of the distributor. From this point, the action of the magneto is exactly the same as the conventional type as regards current distribution and the make-and-break action of the contact breaker

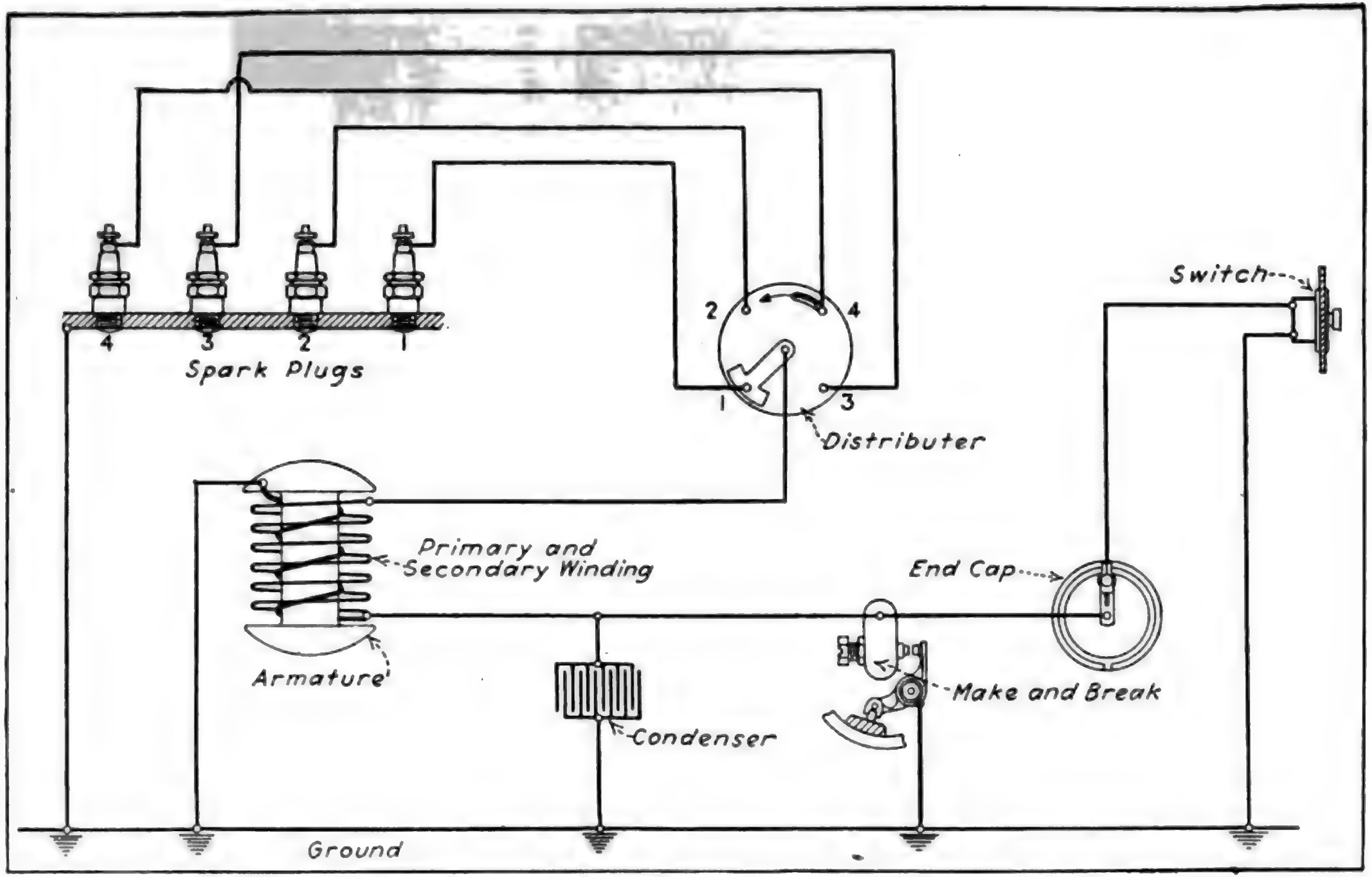

4
3
2
1
Spark Plugs
2
4
1
3
Distributer
Switch
Primary and Secondary Winding
End Cap
Armature
Condenser
Make and Break
Ground

Fig. 151.—Ignition Wiring Diagram of Four-Cylinder Ignition Magneto.

interrupts the primary circuit to secure a sharp break at the time of greatest flow of magnetic flux and a consequently high stepping up of the current value due to inductive effect in the transformer coil.

Timing Magneto Ignition System.—An ideal method of magneto placing and one followed by a large number of manufacturers is shown at Figs. 153 and 154. In these the device is fitted to a four-cylinder engine, and as the armature must be driven at the same speed as the crankshaft, it is necessary to use but one extra gear, that being the same size as the engine shaft pinion and driven by the camshaft speed reduction gear.

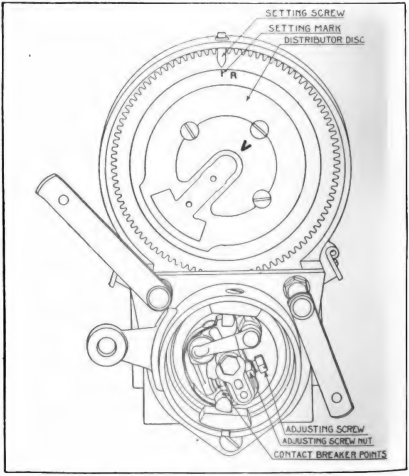

SETTING SCREW
SETTING MARK
DISTRIBUTOR DISC
R
V
ADJUSTING SCREW
ADJUSTING SCREW NUT
CONTACT BREAKER POINTS

Fig. 152.—End View of Typical Magneto Showing Method of Timing.

The magneto armature is turned by a shaft carrying a coupling that extends from the timing gear case. The sketch, Fig. 155, illustrates the best method of timing the magneto, which is one of the direct high-tension type. The position of the various parts is clearly shown. Having fixed the magneto to the engine crankcase, the driving pinion, or one of the members of a flange or Oldham coupling, is put loosely on the tapered end of the armature shaft, and the cover to the distributor and the dust cover of the contact breaker are removed to allow one to control the position of the armature. The motor is now turned over by hand so the piston in the first cylinder is at top center, which can be determined either by watching the crankshaft through a suitable opening in the engine base, by reading the marks on the flywheel rim, or by inserting a wire through a compression relief petcock or spark plug hole, if either of these is at the top of the cylinder.

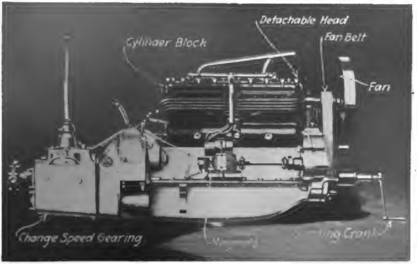


Fig. 153.—Side View of White Model G. N. Motor Showing Location and Method of Driving Ignition Magneto.

The armature of the magneto is then brought to the position indicated in sketch, which represents the fitting of a magneto that is turning clockwise when viewed from the driving end. The distance between the end of the armature and the pole piece should be between 14 and 17 mm. or between .5511 inch and

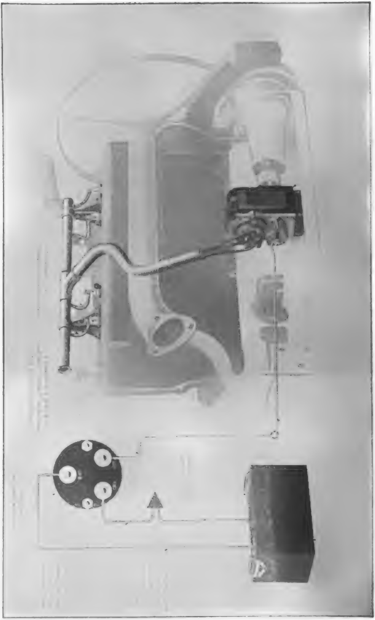


Fig. 154.—Wiring Diagram Showing Ignition System of Packard Motor Trucks.

Google

.6692 inch. (See Fig. 145.) This represents an advance of about .5 inch on a motor with a five-inch stroke. A graphic chart, prepared by the Bosch Company and reproduced at Fig. 156, shows the relation between piston travel and crankshaft movement for engines of different strokes very clearly. The armature is uncovered by removing the flat casing cover lying between the horseshoe magnets, this often carrying the safety spark gap, and normally serving as a lid. If earlier timing be desired for any special purpose, the gap may be widened a trifle, if it be thought the timing is too far advanced, the gap may be

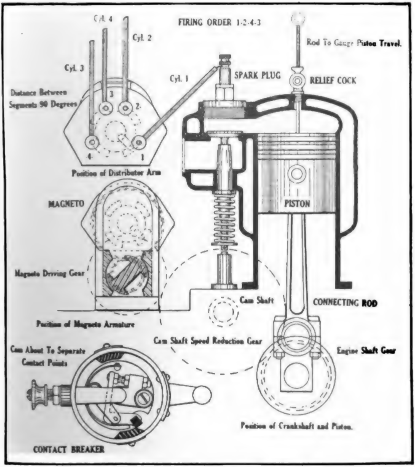
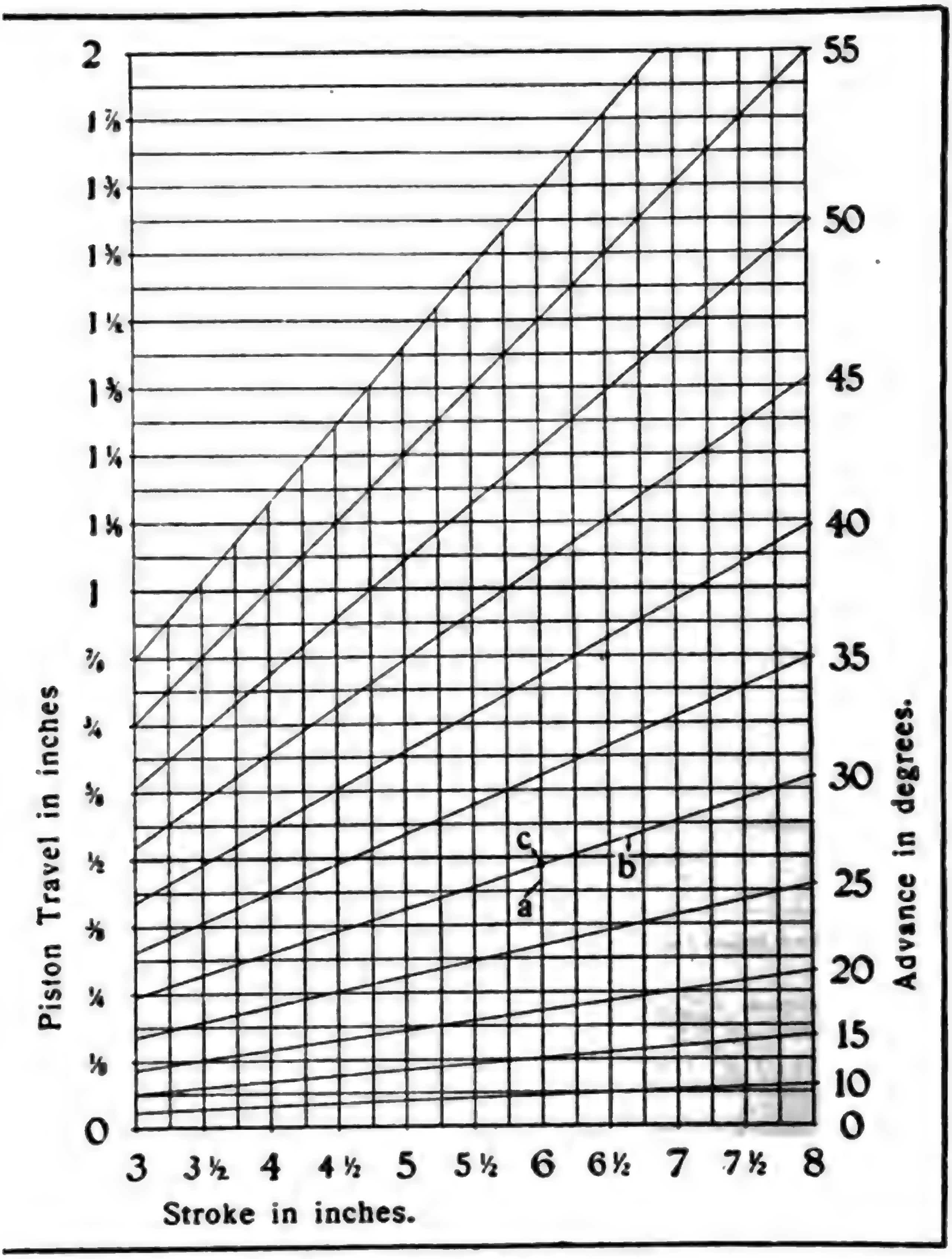

Cyl. 4
FIRING ORDER 1-2-4-3
Cyl. 2
Rod To Gauge Piston Travel.
Cyl. 3
Cyl. 1
SPARK PLUG
RELIEF COCK
Distance Between
Segments 90 Degrees
3
2
4
1
Position of Distributor Arm
MAGNETO
PISTON
Magneto Driving Gear
Cam Shaft
CONNECTING ROD
Position of Magneto Armature
Cam Shaft Speed Reduction Gear
Cam About To Separate
Contact Points
Engine Shaft Gear
Position of Crankshaft and Piston.
CONTACT BREAKER

Fig. 155.—Simplified Diagram Explaining Method of Timing Magneto Ignition System.



g. 156.—Bosch Chart for Determining Advance with Various Strokes.

ssened. The contact breaker is fully advanced at this time and e contact points are just about to separate. Having placed erything in position as described, tighten the coupling on the per shaft of the armature so it will be driven positively.

The connections to the various cylinders must be made in the der they fire. When the cover to the distributor is off, see at hich segment the brush is contacting. The wire to the spark ug in the first cylinder is then led to the terminal corresponding to this segment. Then the plug in the cylinder that is next to fire is coupled to the next segment, and so on. The numbers on the distributor show the order in which the various contacts are brought in contact with the rotating distributing brush, and not that in which the cylinders fire. In the sketch the cylinders fire 1-2-4-3. Therefore, the segment number 3 is coupled to the plug in cylinder 4, and the segment 4 is connected to the plug in cylinder 3, which is thus the last to fire if the explosion takes place first in cylinder 1. The direction of the distributor brush rotation, if driven by the usual form of gearing, is opposite to that of the magneto armature. Obviously, if one cylinder is timed correctly, the remaining members will also fire at the proper time in the cycle of operations. The positions of the armature, distributing brush, contact breaker cam and engine piston are easily ascertained by inspection of drawing.

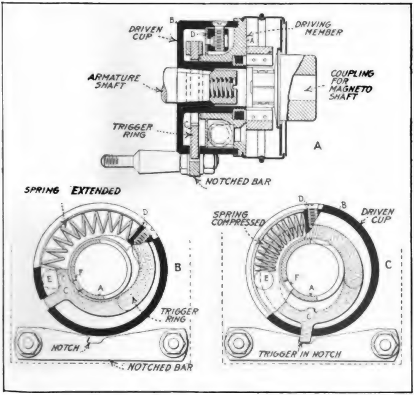

B
DRIVEN CUP
D
A
DRIVING MEMBER
ARMATURE SHAFT
COUPLING FOR MAGNETO SHAFT
TRIGGER RING
C
A
NOTCHED BAR
SPRING EXTENDED
D
B
E
F
C
A
A
TRIGGER RING
NOTCH
NOTCHED BAR
D
B
SPRING COMPRESSED
DRIVEN CUP
C
E
F
A
C
TRIGGER IN NOTCH

Fig. 157.—Diagrams Explaining Action of Eisemann Impulse Starter.

Impulse Starters.—Special forms of couplings, as illustrated at Fig. 157, may be used to drive the magneto armature. This provides a hot spark even when cranking slowly, as the armature speed is accelerated by a spring arrangement so the speed approximates that obtained when the engine is turning over under power. The device illustrated is known as the Eisemann impulse starter coupling. This may be attached to any model of Eisemann magneto and is said to have no effect upon its regular operation except at slow speeds, when it causes the armature to rotate in a series of jumps instead of at a uniform speed.

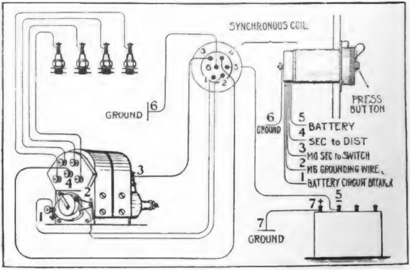

SYNCHRONOUS COIL
3
4
6
5
1
2
PRESS BUTTON
GROUND 6
6 GROUND
5
BATTERY
4
SEC to DIST
3
MG SEC to SWITCH
2
MG GROUNDING WIRE
1
BATTERY CIRCUIT BREAKER
3
4
2
1
7 +
5
7
GROUND

Fig. 158.—Wiring Diagram of Bosch Dual Ignition System.

These jumps cause the armature to cut the lines of force of the magnets quickly, or at the same speed that it does when the motor is revolving swiftly, so that a hot spark is generated. This removes any necessity for auxiliary battery ignition for starting on heavy duty motors, for a hot fat spark is generated at any speed, regardless of how slowly the crank is turned. The coupling consists of a driving tube A in the center and a driven cup B enclosing the device, the two being connected by a spring. Within the driven cup is a loose ring C, known as the trigger. this ring having a lip which extends through a slot on the periphery of the cup. At the bottom of the coupling is a notched bar, so positioned that as the cup revolves the notch registers with the slot in the cup, so that the trigger lip drops down by gravity and thus locks the cup against rotation. This is the position shown in the view at C. On the outside of the trigger ring is a cam which engages a corresponding cam cut in the driving tube. When the lip has engaged the notched bar and the cup ceases to rotate, the driving tube continues to turn. This turning compresses the spring which is seated against a driving pin on the tube and a block fixed to the cup. At a predetermined point the cam on the trigger ring engages that on the tube, and lifts the trigger far enough for the lip to disengage the notched bar, so that the compression of the spring spins the cup around in a clockwise direction.

The magneto armature is connected with the cup, and so as the cup spins around the armature is given a quick twist, producing a hot spark. At slow speed, as the cup revolves it is caught again and again by the trigger, but when the motor fires, the speed is so increased that the trigger ring, by its own weight, becomes a ring governor, and centrifugal force keeps it from dropping down the slot. In this state the coupling acts as a dead connection between the drive and the armature, a small lug on the inside of the trigger ring, at the point where the lip juts out, engaging a notch in the driving tube, and this providing a positive drive as long as the speed is maintained. The device includes the standard Oldham coupling for connection with the shaft, as shown in sectional view at A.

If the magneto is a low tension form, a separate transformer coil is needed to "step up" the low tension armature current to one of sufficient voltage to jump the gap at the spark plugs. With this arrangement a battery can be used to make the engine start easier, though impulse starters now developed greatly reduce the labor involved in hand cranking large truck engines. A typical diagram of this method of ignition is shown at Fig. 146.

Dual Magneto Systems.—When the high-tension magneto was first introduced it was looked upon in some quarters by conservative manufacturers and motorists with some degree of suspicion, as its reliability had not been thoroughly established. Sometimes difficulty was experienced in starting a large engine directly from the magneto because it could not be turned over fast enough with the hand crank to turn the magneto armature at sufficient speed to produce a strong spark. In order to provide an emergency system of ignition and one that could be used

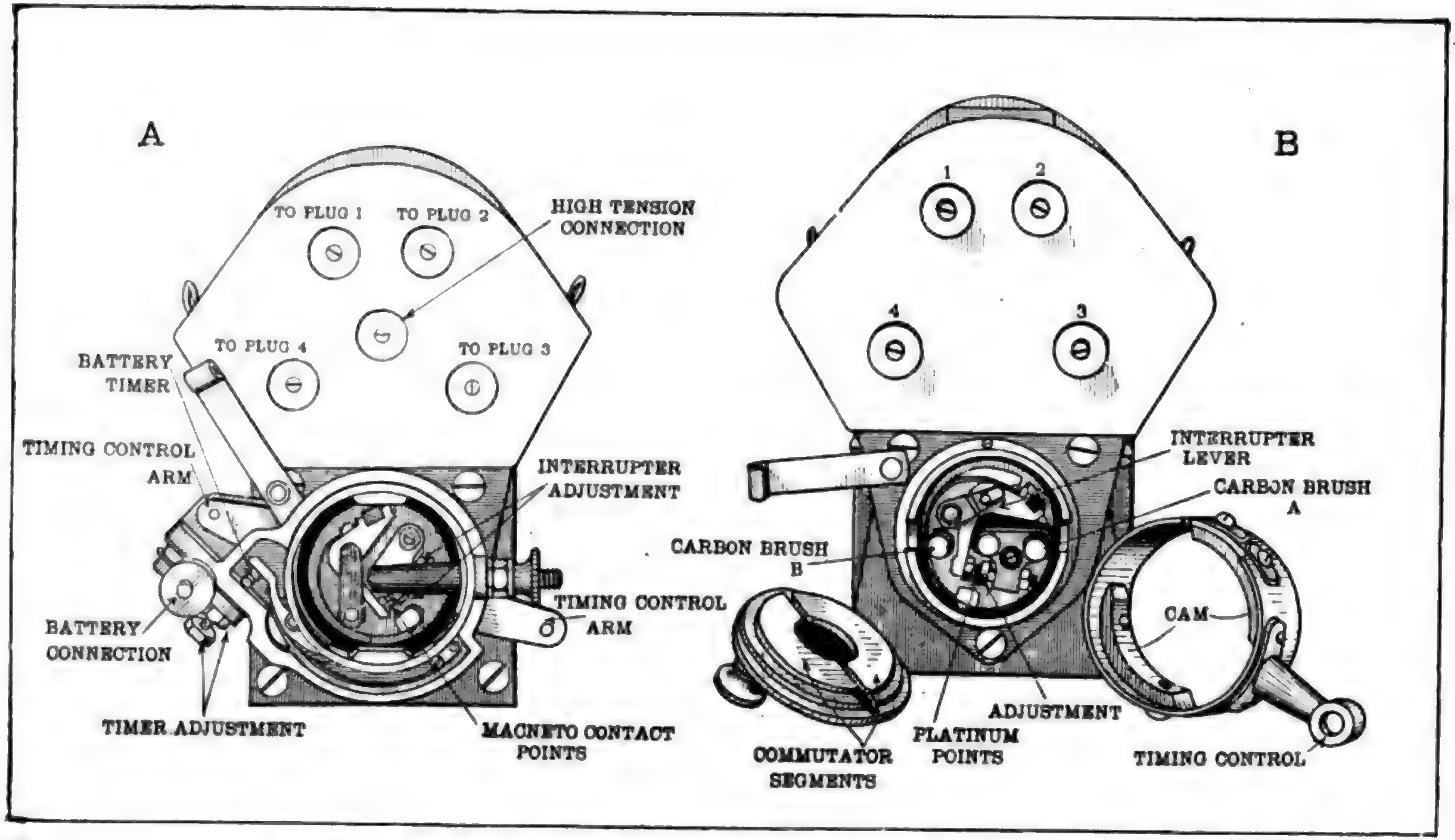

A
TO PLUG 1
TO PLUG 2
HIGH TENSION CONNECTION
TO PLUG 4
TO PLUG 3
BATTERY TIMER
TIMING CONTROL ARM
INTERRUPTER ADJUSTMENT
TIMING CONTROL ARM
BATTERY CONNECTION
TIMER ADJUSTMENT
MAGNETO CONTACT POINTS
B
1
2
4
3
INTERRUPTER LEVER
CARBON BRUSH A
CARBON BRUSH B
CAM
ADJUSTMENT
PLATINUM POINTS
COMMUTATOR SEGMENTS
TIMING CONTROL

Fig. 159.—Contact Breakers for Bosch Magneto Double Ignition System. A—Arrangement for Dual Ignition. B—The Duplex Type.

for starting, the makers of high-tension magnetos evolved what are termed "dual systems." The magneto utilized is practically the same as that used in the simply high-tension systems, except that the contact breaker had a battery timer added which was used to interrupt a battery current. The reason for adding the battery timer and not using the magneto contact breaker was that a short contact was necessary to obtain satisfactory operation from batteries, which the regular magneto contact breaker did not furnish. As the writer has previously explained,

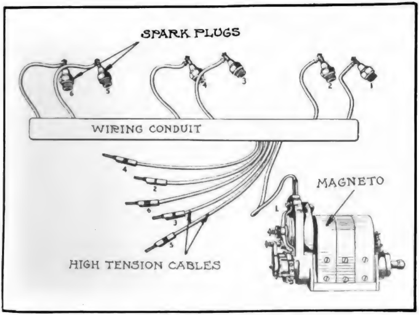


Fig. 160.—How High Tension Magneto Wiring is Carried by an Insulated Conduit.

the points of a magneto contact breaker are kept in contact until interrupted by the cam. If these were used on a battery the current would be flowing through them all the time they were in contact, which would produce current waste. With the battery timer incorporated on the contact breaker the circuit is established only at the instant the spark is needed in the cylinder.

The Bosch Dual System.—This is shown at Fig. 158, has six terminals on the back end of the coil. The coil is attached to the dashboard, as indicated, in the upper right-hand corner, and carries the switch and the starting button on its face. The coil

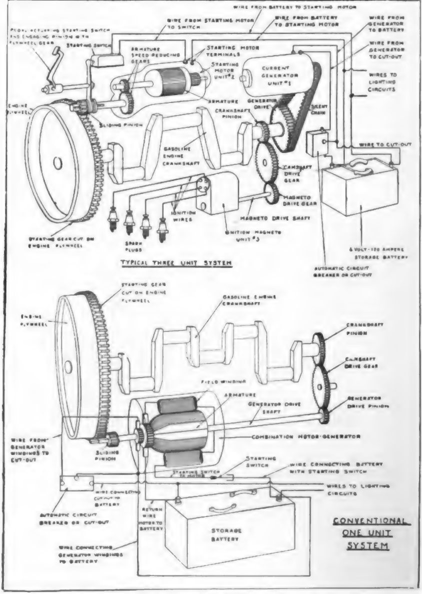

WIRE FROM BATTERY TO STARTING MOTOR
WIRE FROM STARTING MOTOR TO SWITCH
WIRE FROM BATTERY TO STARTING MOTOR
WIRE FROM GENERATOR TO BATTERY
PEDAL ACTUATING STARTING SWITCH AND ENGAGING PINION WITH FLYWHEEL GEAR
STARTING SWITCH
ARMATURE SPEED REDUCING GEARS
STARTING MOTOR TERMINALS
WIRE FROM GENERATOR TO CUT-OUT
STARTING MOTOR UNIT #2
CURRENT GENERATOR UNIT #1
WIRES TO LIGHTING CIRCUITS
ENGINE FLYWHEEL
ARMATURE
GENERATOR DRIVE
SILENT CHAIN
CRANKSHAFT PINION
SLIDING PINION
GASOLINE ENGINE CRANKSHAFT
WIRE TO CUT-OUT
CAMSHAFT DRIVE GEAR
MAGNETO DRIVE GEAR
IGNITION WIRES
MAGNETO DRIVE SHAFT
IGNITION MAGNETO UNIT #3
STARTING GEAR CUT ON ENGINE FLYWHEEL
SPARK PLUGS
6 VOLT-120 AMPERE STORAGE BATTERY
TYPICAL THREE UNIT SYSTEM
AUTOMATIC CIRCUIT BREAKER OR CUT-OUT
STARTING GEAR CUT ON ENGINE FLYWHEEL
GASOLINE ENGINE CRANKSHAFT
ENGINE FLYWHEEL
CRANKSHAFT PINION
CAMSHAFT DRIVE GEAR
FIELD WINDING
ARMATURE
GENERATOR DRIVE SHAFT
GENERATOR DRIVE PINION
WIRE FROM GENERATOR WINDINGS TO CUT-OUT
SLIDING PINION
COMBINATION MOTOR-GENERATOR
STARTING SWITCH
WIRE CONNECTING BATTERY WITH STARTING SWITCH
STARTING SWITCH TO MOTOR
WIRE CONNECTING CUT-OUT TO BATTERY
WIRES TO LIGHTING CIRCUITS
AUTOMATIC CIRCUIT BREAKER OR CUT-OUT
RETURN WIRE MOTOR TO BATTERY
STORAGE BATTERY
CONVENTIONAL ONE UNIT SYSTEM
WIRE CONNECTING GENERATOR WINDINGS TO BATTERY

Fig. 161.—Diagram Showing Relation of Parts of Typical Electric Starting System. That at the Top is a Three-Unit, While the One Shown Below is a One-Unit Form.

is of the vibrator type. The terminals are all numbered and the wiring may be readily traced, as the points to which they connect on the magneto are numbered to correspond. In this system, instead of using the usual high-tension pencil connecting the collector brush to the center of the distributor, the high-tension brush terminal 3 is joined to a terminal on the spark coil, while terminal 4 of the spark coil is joined to the central distributing brush 4 of the magneto. Terminal 6 of the coil is grounded, terminal 5 of the coil runs to one of the battery terminals, the other one being grounded. This leaves terminals 1 and 2 on the coil, No. 1 being connected to a terminal at the side of the battery contact breaker, while terminal No. 2 attaches to a terminal on the side of the magneto contact breaker. With a system of this kind it is possible to short circuit the coil by pressing in on a starting button, which makes the vibrator buzz even if the primary contact breaker on the magneto is not making contact. This permits of starting the engine directly on the spark when they are of the four- or six-cylinder form, providing they have not been stopped long enough for the gas to leave the cylinders.

Duplex System.—The "duplex" system differs from the "dual" system in the method of action. Instead of using a separate battery timer, as shown at A, Fig. 159, and an induction coil having its high tension of secondary lead connected to the central distributing brush of the distributor, the auxiliary brush A on the magneto contact breaker, as shown at B, Fig. 159, is used, and the winding on the magneto armature is used to intensify the current from the batteries in connection with a simple form of dash coil having only a primary winding, as the high tension current is delivered from the armature winding the same collecting brush serves to conduct the secondary current to the distributor in either case, regardless of the source of primary current. The "duplex" system will not furnish ignition if the armature windings are defective, while the "dual" system will. The "dual" system is also more economical of battery current.

Self-Starters for Gasoline Engines.—One of the disadvantages of the gasoline engine which has often been advanced by those favoring steam or electric power is that it is difficult to start it in some cases and various means were devised to overcome the objection advanced. The early gas engines fitted with poorly designed carburetors and inadequate ignition systems were often difficult to set in motion, but as the gasoline engine was improved and the multiple-cylinder form gained in favor, those used during the past few years have been exceptionally easy to

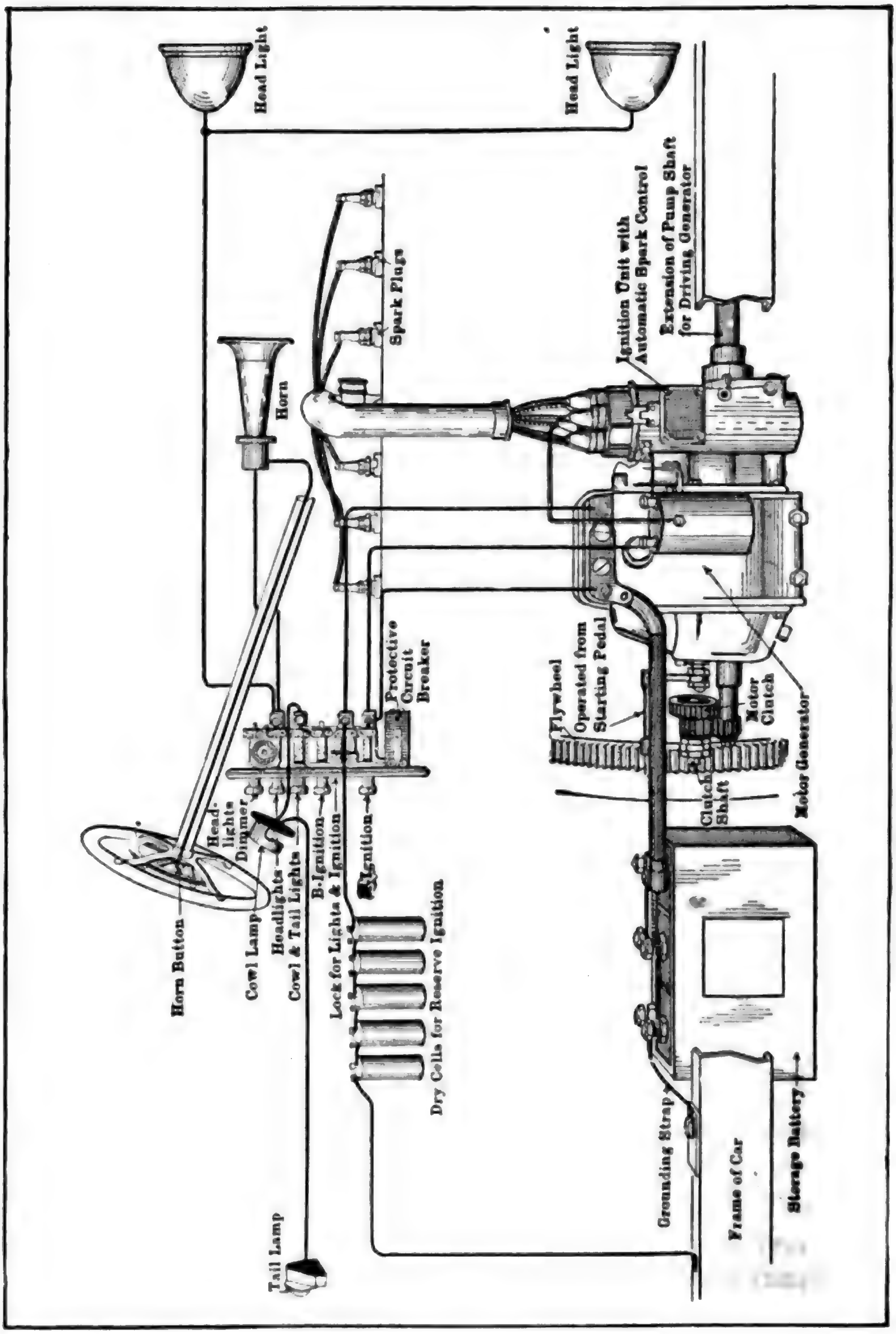

Head Light
Head Light
Ignition Unit with Automatic Spark Control
Extension of Pump Shaft for Driving Generator
Spark Plugs
Horn
Protective Circuit Breaker
Flywheel Operated from Starting Pedal
Motor Clutch
Motor Generator
Clutch Shaft
Head-lights Dimmer
Horn Button
Cowl Lamp
Headlights
Cowl & Tail Lights
B-Ignition
Lock for Lights & Ignition
A-Ignition
Dry Cells for Reserve Ignition
Tail Lamp
Grounding Strap
Frame of Car
Storage Battery

Fig. 162.—The Delco One-Unit Starting, Lighting and Ignition Systems.

start by some form of starting handle or crank, and often a quarter turn of that member is sufficient to set the engine in motion if it was in proper adjustment and the various auxiliary groups were functioning properly. At the present time the improvements made in the gasoline automobile have been more in the nature of detailed refinement and those engaged in producing motor cars have studied more carefully the various points which make automobiles more convenient and more easily operated. The requirements of the present day cannot be met solely by easy cranking, because this feature is common to all automobiles, from the smallest runabout to the heaviest touring car or truck.

The present demand on the part of passenger car owners is for engines that are equipped with some form of mechanism which will make them self-starting; that is, so that they may be set in motion by merely pressing a button from the seat and not by the usual form of hand crank at the front of the engine. The starting handle has always been a danger point, and many broken arms and fractured wrists have resulted from a premature explosion of gas in the cylinders which forced the starting handle backward and against the arm or hand of the person starting the engine. There is some difference of opinion on the part of truck designers as to the desirability of putting a self-starter on such vehicles, which should be as simple as possible to secure maximum reliability of operation. The average truck driver or his assistant must be an able-bodied man, and the task of starting a truck motor is not difficult for a person of average strength. Most truck makers at this time are not fitting electric starting systems, but brief mention of the operating principles is desirable in the event of a demand on the part of the buying public becoming such that starters must be applied on trucks as well as on passenger cars.

Electric Starting Systems.—Starters utilizing electric motors to turn over the engine are now considered the ideal starting device. The capacity is very high, as the motor may draw contact from a storage battery and keep the engine turning over for half an hour on a charge. The objection formerly advanced against their use, that it requires considerable complicated and costly apparatus which is difficult to understand and which requires the services of an expert electrician to repair should it get out of order is no longer true, because the development has greatly simplified the units and the various systems are now well understood by all. Electric starting and lighting systems have been made in many forms; though the basic principles of operation are practically the same in all systems, they can be grouped in several main classifications. It will not be possible to describe all in a general treatise of this nature, but if the features of the leading systems are outlined it will not be difficult for the motorist or repairman to become familiar with the principles of other systems which may be different only in points

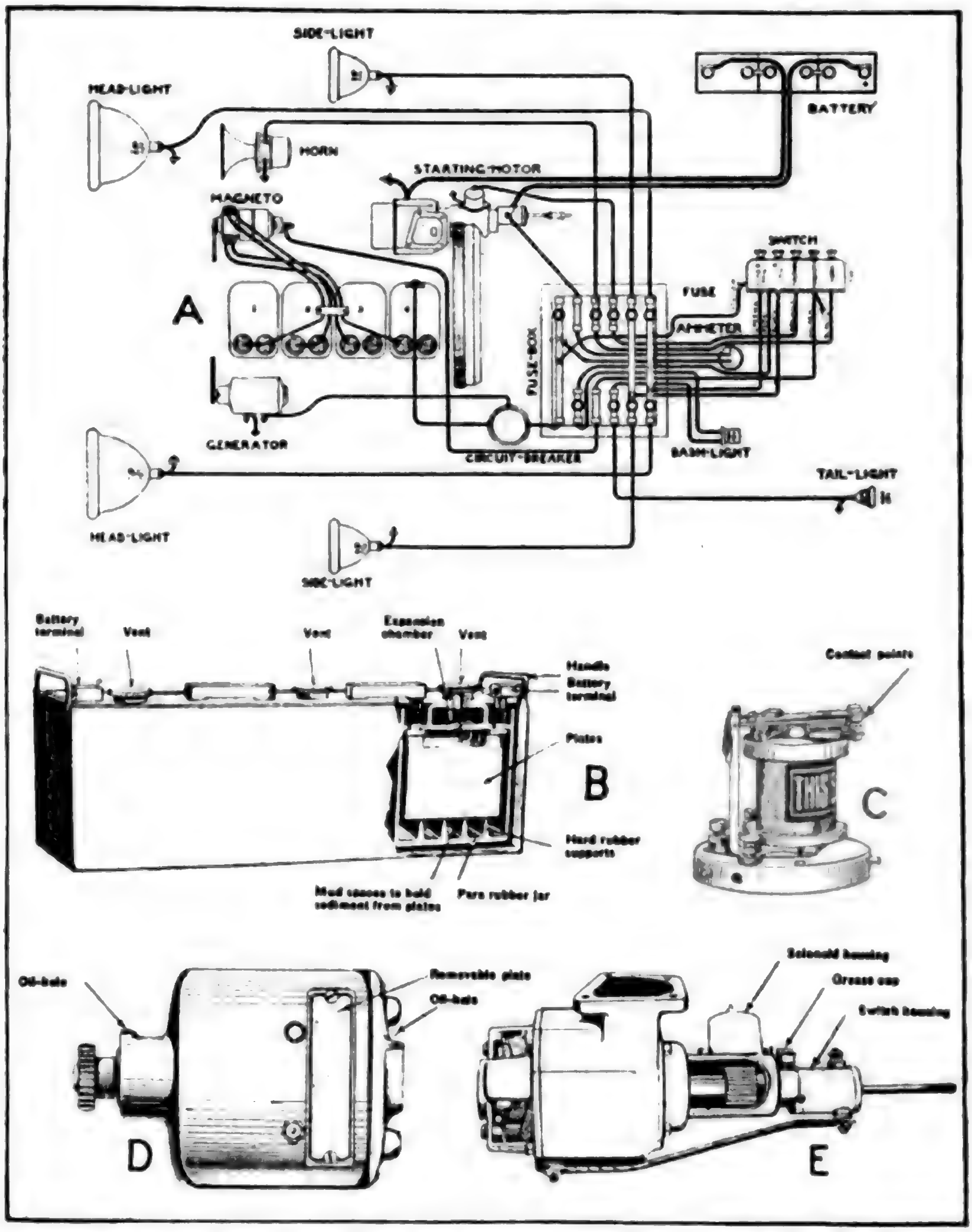

SIDE-LIGHT
HEAD-LIGHT
HORN
BATTERY
STARTING-MOTOR
MAGNETO
SWITCH
FUSE
A
AMMETER
FUSE-BOX
GENERATOR
CIRCUIT-BREAKER
DASH-LIGHT
TAIL-LIGHT
HEAD-LIGHT
SIDE-LIGHT
Battery terminal
Vent
Vent
Expansion chamber
Vent
Handle
Battery terminal
Plates
B
Hard rubber supports
Mud spaces to hold sediment from plates
Pure rubber jar
Contact points
C
Oil-hole
Removable plate
Oil-hole
D
Solenoid housing
Grease cup
Switch housing
E

Fig. 163.—Wiring Diagram of the Auto-Lite System at A. B—Part Sectional View of Storage Battery. C—Automatic Circuit Breaker. D—Current Generator. E—Starting Motor.

of minor detail. Not only do the individual systems vary in detail, but the components of the same system are often of different construction when used on cars of different makes.

The standard equipment must include three main component parts; namely, the generator, which is driven by the engine and which produces electric current to keep the storage battery charged, and the starting motor, which is in mechanical connection with the engine and in electrical connection with the storage battery when it is desired to turn the engine over for starting. If the motor and generator are combined in one instrument, the starting system is known as the "one-unit" type. If the motor is one appliance and the generator another, the system is said to be a "two-unit" type. Each of these has advantages, and both forms have demonstrated that they are thoroughly practical. In addition to the three main items enumerated, various accessories, such as switches, ammeters, connectors, wiring, protective circuit breakers, automatic current regulators, etc., are necessary for the convenient distribution and control of the electric current.

The arrangement of the parts of a typical "one-unit" system in which the motor generator is used only for starting and lighting is shown at Fig. 161. This shows the location of the various parts in their relation to the other components of the motor car power plant. The motor generator is usually mounted at the side of the engine and is driven by the drive shaft when used as a generator and serves to drive the engine through a gear on the flywheel when it is used as a motor. The ignition current is supplied from an entirely independent source not shown—a high-tension magneto. The starting switch and that controlling the lighting system are nearly always placed on the dash, while the storage battery is carried under the floor of the tonneau in a pleasure car or on the running board of the heavier vehicles. It will be observed that the armature carries two commutators, one of which is used when the armature is driven by the engine and when the device serves as a current generator, the other being employed when the operating conditions are reversed and the electrical machine is driven as a motor to turn over the engine crankshaft. When the device is driven as a generator the small sliding pinion on the short end of the shaft is out of engagement with the spur gear cut on the flywheel exterior. When it is desired to start the engine, the spur gear is meshed with the member cut on the flywheel and the current from the storage battery is directed to the windings of the electric machine, which becomes a motor and which turns over the engine crankshaft. When the device is working as a generator the current developed goes to the storage battery and from that member to the various current-consuming units.

Sometimes the motor and generator are combined in one casting and the system so provided is erroneously called a "one-unit" system. In reality, such a system is a "two-unit" system, because the electrical machines are uni-functional, instead of performing a dual function, as does any combined motor generator.

Two-Unit System.—The parts of a two-unit starting and lighting system are shown at top of Fig. 161. This system is sometimes called a "three-unit" system on account of having a source of independent current supply for ignition purposes. As will be observed, the generator is driven from the motor crankshaft by silent chain connection, one of the terminals passing through the cut-out device and to the storage battery, the other terminal running directly to the storage battery terminal having a short by-pass or shunt wire attached to the cut-out. All the time that the engine is running the generator is delivering electricity to the storage battery. It will be observed that the storage battery is also coupled to the lighting current which is shown at the right of the illustration and to the electric starting motor as indicated. One of the storage battery terminals is joined directly to the switch terminal by a suitable conductor; the other goes to one of the terminals on the starting motor, while the remaining terminal of the starting motor goes to the switch. In this system, when the small sliding pinion is meshed with the flywheel gear the switch is thrown on simultaneously and the current that flows from the storage battery through the windings of the starting motor rotates the engine crankshaft by means of a reduction gear shown. As soon as the engine starts the foot is released and a spring pulls the switch out of contact and also disengages the sliding pinion from the flywheel gear. The actual application to a gasoline engine fitted with a starting motor and generator in one-unit form is shown at Fig. 162. It will be observed that the starting motor is mounted at the back end of the crankcase in such a position that the sliding pinion may be brought into engagement with the flywheel gear.

Electrical starting systems may be operated on either six, twelve or twenty-four-volt current, the former being generally favored because the six-volt lamps use heavier filaments than those of high voltage and are not likely to break due to vibration. It is also easier to install a six-volt battery, as this is the standard voltage that has been used for many years for ignition and electric lighting purposes before the starting motors were applied. In referring to a system as a "one-unit" system of lighting, starting and ignition, one means that all of these functions are incorporated in one device, as in the Delco system shown at Fig. 162. If one unit is used for generating the lighting and starting current and also is reversible to act as a motor, but a separate ignition means is provided, such as a high-tension magneto, the system is called a "two-unit" system. The same designation applies to a system when the current generating and ignition functions are performed by one appliance and where a separate starting motor is used. The three-unit system is that in which a magneto is employed for ignition, a generator for supplying the lighting and starting current and a motor for turning over the engine crankshaft. A system of the three-unit type is shown at Figs. 163 and 164.

Starting System Parts.—The generator, as will be apparent from its name, is utilized for producing current. This is usually a miniature dynamo patterned largely after those that have received wide application for generating current for electric lighting of our homes and factories. The generators of the different systems vary in construction, some having a permanent magnetic field, while others have an excited field. In the former case permanent horseshoe magnets are used as in a magneto. In the other construction the field magnets as well as the armature are wound with coils of wire. In all cases the dynamo or generator should be mechanically driven from the engine crankshaft either by means of a direct drive, by silent chain or through the medium of the timing or magneto operating gears. All the current produced by the generator and not utilized by the various current-consuming units, such as the lamps, ignition system, electric horn, etc., is accumulated or stored in the storage battery and kept in reserve for starting or lighting when the engine is not running or for lighting and ignition when the car is being run at such low speed that the generator is not supplying current.

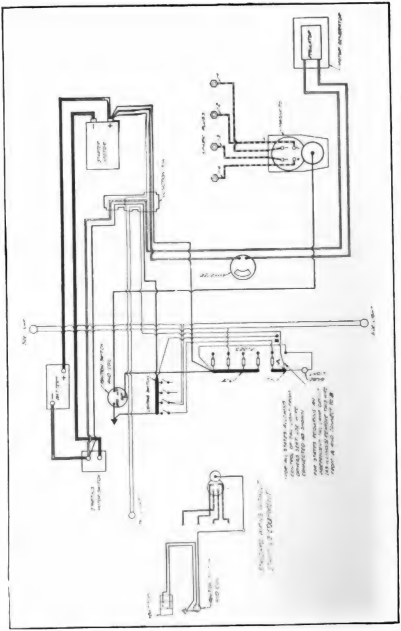


Fig. 164.—Wiring Diagram of Packard Motor Truck Starting and Lighting System.

Storage batteries used in starting systems must be of special design and large capacity in order to stand the high discharge and to perform efficiently under the severe vibration and operating conditions incidental to automobile service. The storage battery may be installed on the running board of the truck, under the body, or under the seat, the location depending upon the design of the motor and the degree of accessibility desired. The best practice is to set the storage battery in a substantial carrying case held by rigid braces attached to the frame side and cross members. The battery may be set under the body floor boards, a door in these giving ready access to the battery. The starting motor, which takes the place of the common hand crank, is operated by current from the storage battery, and the high speed armature rotation is reduced to the proper cranking speed by suitable reduction gears. The construction of the starting motor is practically the same as that of the dynamo, and it operates on the same principles, except that one instrument is a reversal of the other.

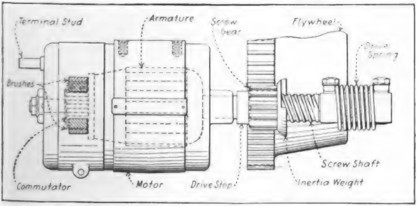


Fig. 165.—Starting Motor Showing Application of the Automatic Pinion Shift by Which the Flywheel Driving Pinion Engages the Large Gear by Motor Armature Shaft Retention.

A typical starting motor of modern design is shown at Fig. 165, which is that utilized with the Delco two-unit system; the small pinion on the armature shaft is shifted automatically. There is a spiral thread cut into the pinion, and as soon as the armature starts turning it screws the pinion into engagement with the flywheel gear. As soon as the engine starts, the pinion is shifted out of mesh automatically. This is a very popular form of drive and is found on a large number of automobil engine starting motors.

The dynamo shown at Fig. 166 is a simple form, as it is woun so that no governor is necessary and the windings are so proportioned that it may be driven at high speed without danger an yet deliver a current of electricity at comparatively low moto speed. The side sectional view is the Delco generator, used i

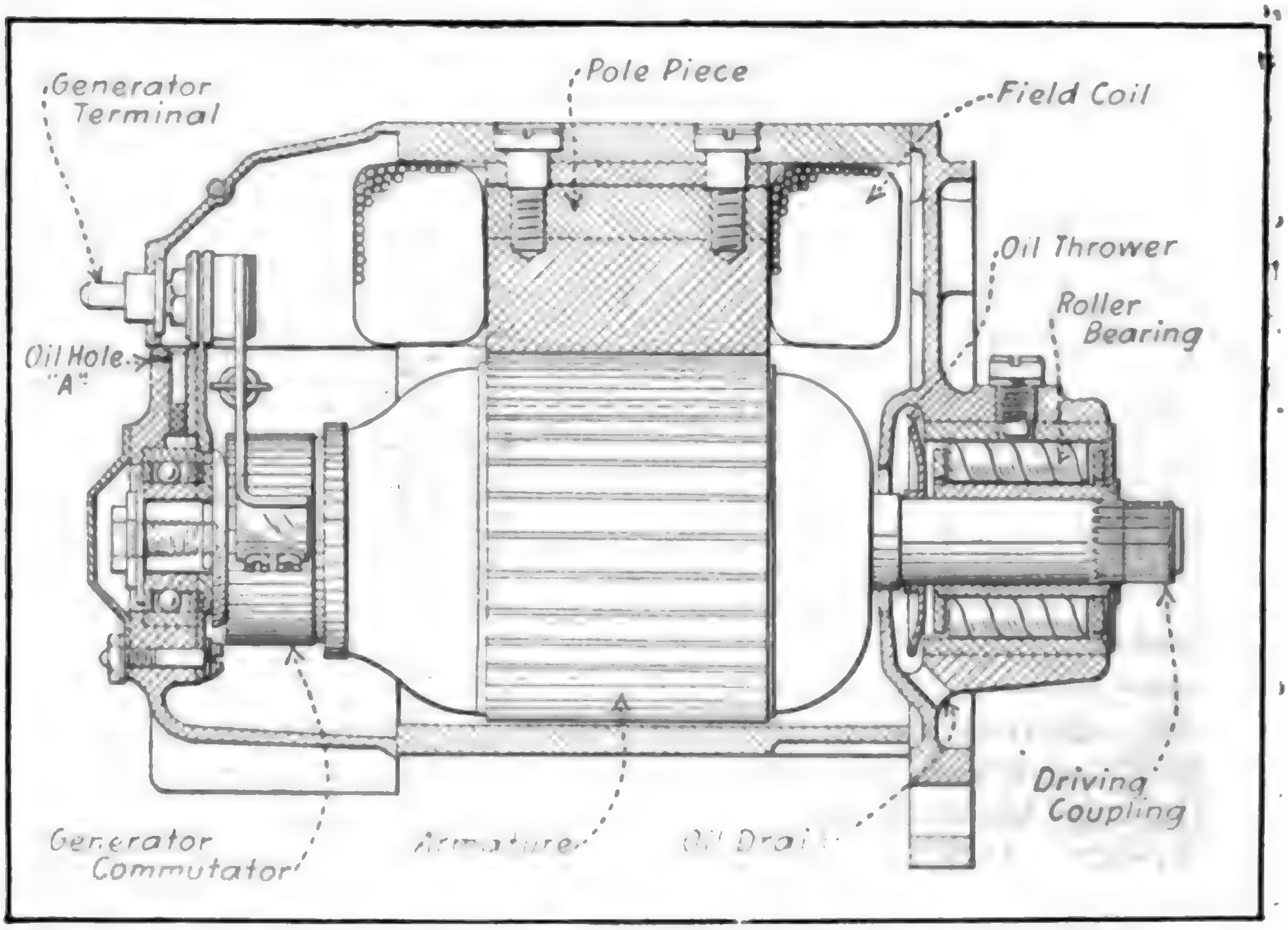


Fig. 166.—Current Generator of the Delco Two-Cylinder System.

connection with the latest two-unit system. The illustration at Fig. 167 shows the arrangement of the brushes, particularly the third brush, for regulating the current output. This differs from the ordinary shunt wound generator in that the shunt field current, instead of being taken from the regular brushes of the generator, is taken from an auxiliary or regulating brush which bears on the commutator between the regular brushes. With this method of regulation a strong shunt field is secured at low speeds which causes the generator to commence charging at low speeds. As the speed increases, the amount of voltage that is applied to the shunt field is decreased, although the total voltage between the main brushes may be increased. This prevents the output of the generator from increasing with the increased speed, and at the higher speeds it causes the output of the generator to be decreased.

In order to secure automatic operation of a lighting and starting system, several mechanical and electrical controls are needed, these including the circuit breaker, the governor, which may be either mechanical or electrical, and the operating switches. The circuit breaker or automatic cut-out is a device to retain current in the storage battery under such conditions that the battery current is stronger than that delivered from the generator. If no circuit breaker was provided, the storage battery could discharge back through the generator winding. The circuit breaker, as shown at Fig. 163, C, is usually operated by an electromagnet, and may be located either on the generator itself or any other convenient place on the car, though in most cases the circuit breakers are usually mounted on the back of the dashboard. This device is absolutely automatic in action and requires little attention.

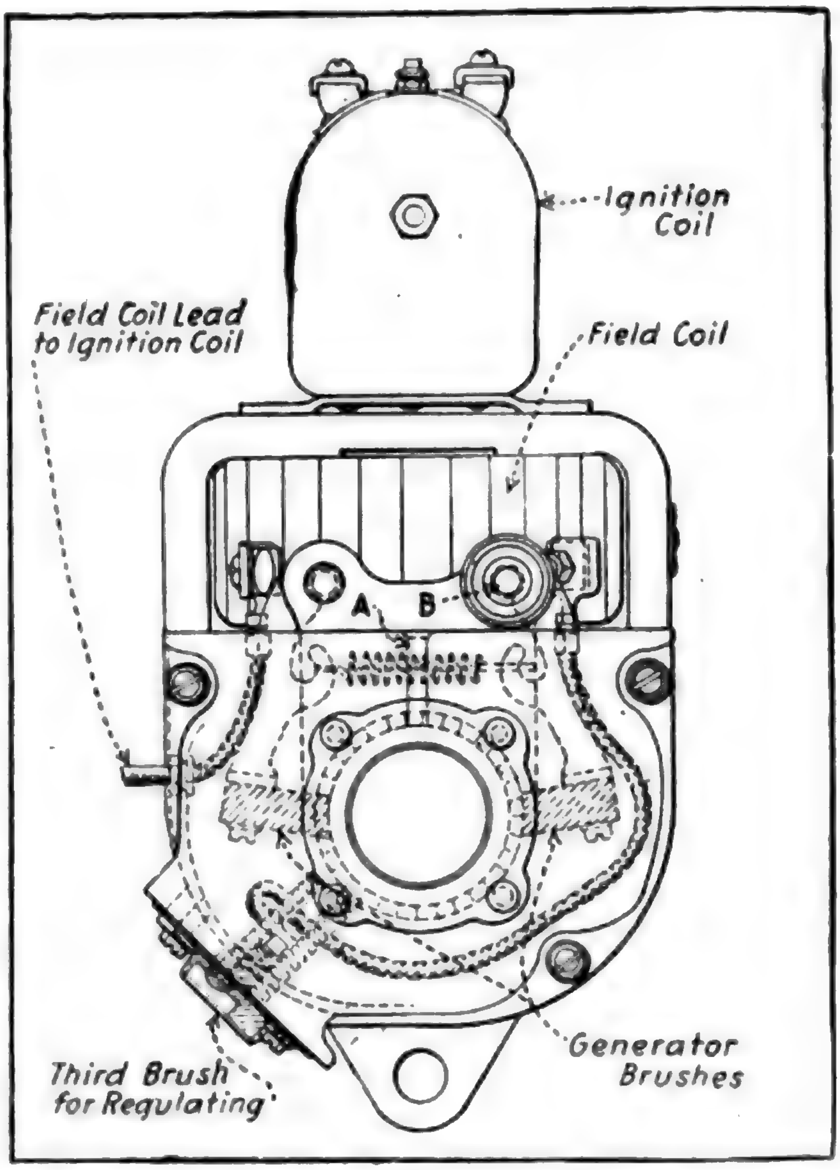


Fig. 167.—View of Commutator End of Delco Generator Showing Position of Third Brush for Current Regulating Purposes.

Governor Action.—The governors are intended to prevent excessive output of current from the generator when the engine runs at extremely high speed. Two types have been used, one mechanical, operated by centrifugal force, and the other, electrical. The former, which is now seldom used, is usually a friction drive mechanism mounted on the generator shaft, which automatically limits the speed of the dynamo armature to a definite, predetermined number of revolutions per minute. The maximum current output is thus held to the required amount independently of the speed at which the car is being driven. The use of this device minimizes the possibility of overheating the generator or overcharging the battery at high engine speeds. The electrical system of governing does not affect the speed of the armature, but controls the output of the generator by means of armature reaction, a buckling coil or a revised series field winding. The governors usually permit a maximum generator output of from ten to twelve amperes, though the normal charging current is less than this figure.

Function of Amperemeter.—In practically all systems an amperemeter is mounted on the dash so it can be readily inspected by the driver, this indicating at all times the amount of current being produced by the dynamo or drawn from the battery. If the indicating needle of the amperemeter points to the left of the zero point on the scale it means that the battery is furnishing current to the lights or other current-consuming units or discharging. When the needle points to the other side of the scale it means that the generator is delivering current to the battery which is charging it; the amount of charge or discharge at any time can be read from the scale on the face of the amperemeter. Some of these instruments have the words "charge" and "discharge" under the scale, in order to enable the operator to read the instrument correctly.

Another important element is the lighting switch, which is usually mounted at some point within convenient reach of the car driver. This is usually placed on an instrument board on the back of the cowl in connection with the other registering instruments. As ordinarily constructed, the switches are made up of a number of units, as the wiring is such that the head, side and tail lamps may be controlled independently of each other. For simplicity and convenience of installation, the switch is usually arranged so that all circuits are wired to parallel connecting members or "busbars" placed on the back of the switch, as shown at Fig. 162. As but little current passes through the lighting switch, the contacts are not as heavy in construction as are those of the starting switch, which are of heavy copper.

Complete instructions for care and repair and wiring diagrams of typical motor truck electrical systems will be found in Chapter II.

CHAPTER VI

MOTOR TRUCK CLUTCH AND GEARBOX

Why Clutch is Necessary—Clutch Forms and Requirements—How Friction Clutches Transmit Power — Typical Clutch Types — Why Change-Speed Gearing is Necessary—Selective Change Speed Gearing — The Dodge Change Speed Gear — Combined Jackshaft and Gearbox—The White Clutch and Gearbox—Individual Clutch Transmission—Transmission for Four Wheel Drive—Planetary Gearing of Ford Cars—Ten Speed Transmission—Shifting Clutch Transmission.

The main links in the power transmission and control system between the engine and traction wheel driving mechanism are the clutch and gearbox. The former is utilized to connect the engine power delivered at the flywheel end of the engine crankshaft to the change-speed gears or to disconnect it at will. The function of the change-speed gearing and its operation is to be fully discussed after consideration has been given to the function and types of clutches generally used. Clutches and gearsets of modern design give little trouble and require a modicum of care if properly handled. Defective operation can usually be traced to careless driving rather than to defects in either construction or design.

Why Clutch is Necessary.—In order to secure a better understanding of the general requirements of clutching devices it will be well to consider the conditions which make their use imperative when a motor car is propelled by a hydrocarbon motor. If a steam engine or an electric motor are installed as prime movers it is not necessary to include any clutching device or gearset between them and the driving wheels, and these members may be driven directly from the power plant if desired. With either of the forms mentioned the power is obtained from a separate source which may be uncoupled from the motor by the simple movement of a throttle valve or switch lever. Steam and electric motors are also capable of delivering power in excess of their rating and are more flexible than internal combustion power plants.

If steam is the motive agent, it is generated and contained in a special device known as a boiler, and the amount of power delivered by the engine to which the boiler is connected will vary with the amount of steam admitted and its pressure. If the steam supply is interrupted entirely the engine and the car which it drives are brought to a stop. When it is desired to start again a simple movement of the throttle-valve lever will permit the steam to flow from the boiler to the engine cylinders again, and the vehicle is easily set in motion. If it is desired to reverse the car, the steam flow is reversed by a simple mechanical movement and the engine will run in the opposite direction to that which obtains when the car is driven in a forward direction.

If an electric motor drives a vehicle the electrical energy is secured from a group of storage batteries. When these are fully charged varying amounts of electric current may be drawn from them and allowed to flow through the windings of the field or armature of the motor and different ratios of power or speed obtained. The vehicle is easily started by completing the circuit between the motor and the source of current and stopped by interrupting the supply of electrical energy. As the flow of electricity can be reversed easily by a switch, the car may be driven backward or forward at will, and as the speed may be easily varied by changing the value of the current strength, there is no need of speed changing or reversing gears.

When a gasoline engine is fitted, conditions are radically different than with either a steam or electric power plant. The power developed depends upon the number of explosions per unit time and the energy augments directly as the number of explosions and revolutions of the crankshaft increase. It is not possible to start a gasoline engine when under load because the power is obtained by the combustion of fuel directly in the cylinders, and as there is no external source of power to draw from, it is obvious that the energy derived depends upon the rapidity with which the explosions follow each other. It has been demonstrated that a certain cycle of operation is necessary to secure gasoline-engine action, and it is imperative that the engine revolves freely until it attains sufficient speed to supply the torque or power needed to overcome the resistance that tends to prevent motion of the car before it can be employed in driving the vehicle.

Then, again, it is very desirable that the vehicle be started or stopped independently of the engine. With a steam or electric motor the vehicle may be started just as soon as the driving power is admitted to the prime mover, but with a gasoline engine it is customary to interpose some device between the engine and driving wheels which make it possible to couple the engine to the wheels or driving gearing and disconnect it at will. The simplest method of doing this is by means of some form of clutching device which will lock the driving shaft to the crankshaft of the engine when desired, yet permit instant release.

Clutch Forms and Their Requirements.—Clutch forms that have been applied to automobile propulsion are usually of the frictional type, though some have been devised which depend upon hydraulic, pneumatic, or magnetic energy. Those which utilize the driving properties of frictional adhesion of various materials are most common and have proven to be the most satisfactory in practical application. The most important requirement in considering clutch forms is that such devices must be capable of transmitting the maximum power of the engines to which they are fitted without any power loss due to slipping. Such a clutch must be easy to operate and but minimum exertion should be required of the operator. When the clutch takes hold, the engine power should be transmitted to the gearset and driving means in a gradual and uniform manner, or the resulting shock may seriously injure the mechanism. When released it is imperative that the two portions of the clutch disengage positively so that there will be no continued rotation of the parts after the clutch is disengaged.

The design should be carefully considered with a view of providing as much friction surface as possible to prevent excessive slipping and loss of power. It is very desirable to have a clutch that will be absolutely silent whether engaged or disengaged. If the clutch parts are located in an accessible manner it may be easily removed for inspection, cleaning, or repairs. It is desirable that adjustment be provided so a certain amount of wear can be compensated for without expensive replacement. A simple, substantial design with but few operating parts is more to be desired than a more complex device which may have a few minor advantages, but which is more likely to cause trouble.

The friction clutch in its various efficient types is the one that more nearly realizes the requirements of the ideal clutch. As a result this form is now universally recognized by automobile designers, and all standard gasoline automobiles utilize some form of friction clutch. These devices are capable of transmitting any amount of power if properly proportioned, and permit of gradual engagement and positive disconnection. Most friction clutches are simple in form, easily understood, and may be kept in adjustment and repair without difficulty.

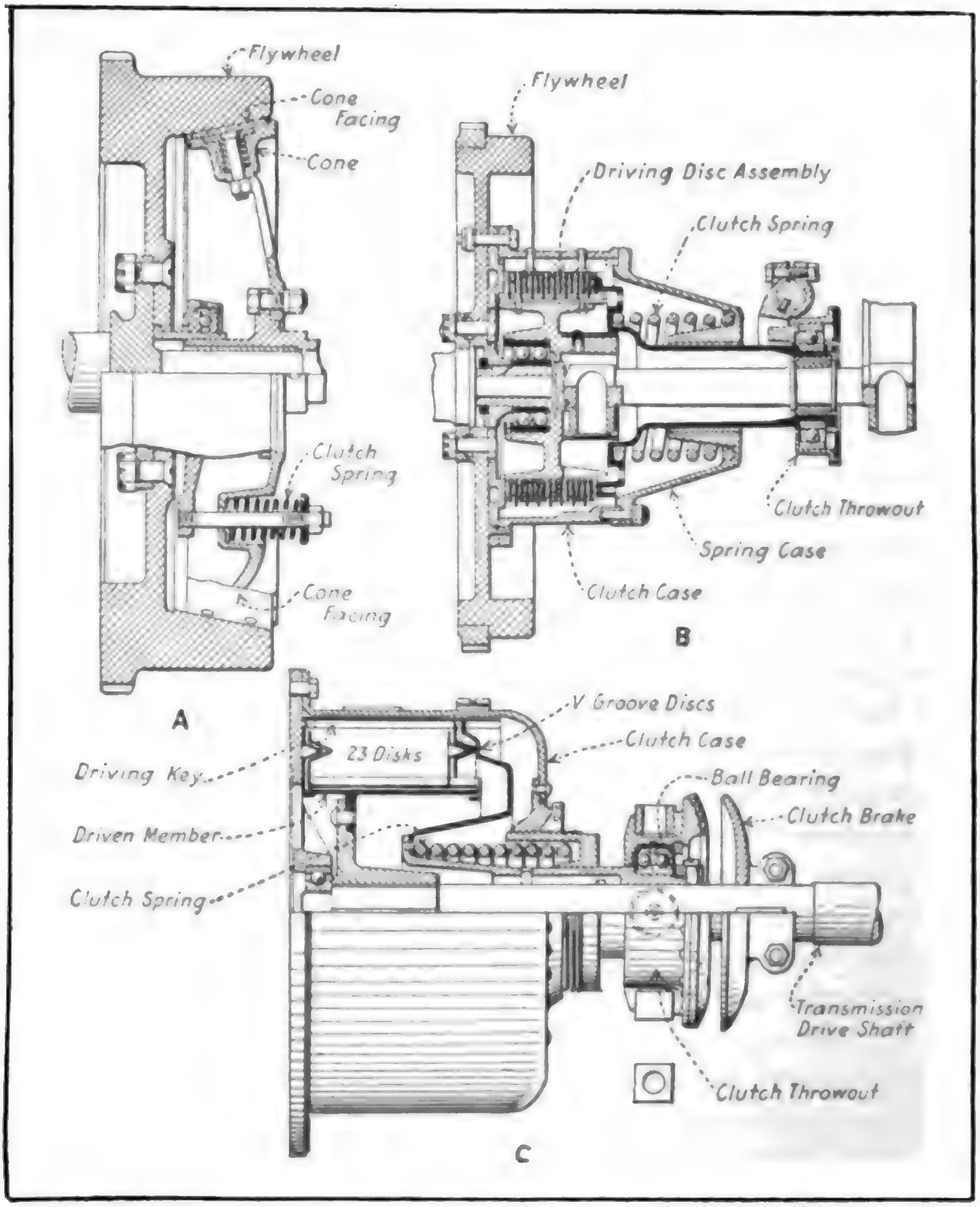

Flywheel
Cone Facing
Cone
Clutch Spring
Cone Facing
A
Flywheel
Driving Disc Assembly
Clutch Spring
Clutch Throwout
Spring Case
Clutch Case
B
V Groove Discs
Clutch Case
Ball Bearing
Clutch Brake
Driving Key
23 Disks
Driven Member
Clutch Spring
Transmission Drive Shaft
Clutch Throwout
C

Fig. 168.—Diagrams Showing Different Clutch Types. A—Simple Cone Clutch. B—Multiple Drive Plate Type. C—Hele-Shaw Multiple Disc Type.

How Friction Clutches Transmit Power.—To illustrate the transmission of power by the frictional adhesion of substances with each other we can assume a simple case of two metal discs or plates in contact, the pressure existing between the surfaces being due to the weight of one member bearing upon the other. If the discs are not too heavy, it will be found comparatively easy to turn one upon the other, but if weights are added to the upper member a more decided resistance will be felt, which will increase directly as the weight on the top disc and consequently the pressure between the disc increases. It may be possible to add enough weight so it will be practically impossible to move one plate without turning the other. It is patent that if one of these plates was mounted rigidly on the engine shaft and one applied to the transmission shaft so that it had a certain amount of axial freedom and pressure of contact was maintained by a spring instead of weights, a combination capable of transmitting power would be obtained. The spring pressure applied to one disc would force it against the other, and one shaft could not turn without producing a corresponding movement of the other.

Types of Clutches.—Friction clutches are made in a great variety, though they may be divided in three main classes. The simplest type is that shown at A, Fig. 168, in which male and female clutch members of the conical type are used. The female cone is machined into the flywheel and forms the driving member, while the male cone is a separate casting faced with friction fabric such as leather or woven asbestos to increase the degree of frictional adhesion to a higher value than would obtain if metal to metal surfaces were employed, and also it secures gradual engagement and a more uniform application of the driving power. The cone is held in normal engagement with the flywheel by a series of clutch springs, as indicated. Light spring pressed plungers are employed beneath the leather facing to prevent the entire surface of the cone engaging when the clutch is first thrown into contact. An advantage in the use of friction facing material is that when this wears it may be easily replaced and there is no injury to the more expensive parts.

A multiple disc clutch is outlined at Fig. 168, B. In this there are two sets of driving plates, one being carried by the casing attached to the flywheel and the other by a disc carrier member from which the drive is transmitted to the gearbox. A large coil spring keeps the discs in contact when it is desired to transmit power. The clutch is released by compressing the spring and allowing the discs to separate. One set of discs is faced with asbestos friction material; the other is plain metal without friction facing.

The important parts of the Packard multiple disc dry plate clutch are shown at Fig. 169. The clutch assembly carrier is bolted to the engine flywheel, and as it is now current practice in dry plate clutches the discs that are driven by the clutch case carries a friction facing, while those that are mounted on and turned with the inner clutch disc carrier are stamped metal plates. The friction fabric faced discs have a series of key ways on their outer periphery which engage with the keys in the clutch case. The other set of discs is provided with a series of keyways which engage with keys on the external periphery of the clutch disc carrier. Driving friction is maintained by a substantial coil spring.

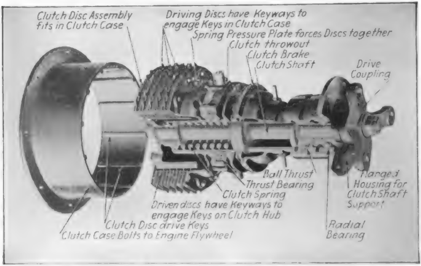

Clutch Disc Assembly fits in Clutch Case
Driving Discs have Keyways to engage Keys in Clutch Case
Spring Pressure Plate forces Discs together
Clutch throwout
Clutch Brake
Clutch Shaft
Drive Coupling
Ball Thrust
Thrust Bearing
Clutch Spring
Flanged Housing for Clutch Shaft Support
Driven discs have Keyways to engage Keys on Clutch Hub
Clutch Disc drive Keys
Clutch Case Bolts to Engine Flywheel
Radial Bearing

Fig. 169.—The Packard Motor Truck Clutch is a Multiple Drive Plate Type, as Can Be Clearly Seen from Part Sectional View Above.

Multiple disc clutches are made in two main forms, the one previously described, which usually operates on the dry plate principle, and the form shown at Fig. 168, C, in which the discs revolve in an oiltight casing and in which none of the discs are faced with friction material. The Hele-Shaw clutch employs all-metal discs having V grooves, as indicated, to give more frictional driving surface, but otherwise works the same as any multiple disc clutch. The construction of the Hele-Shaw is clearly shown at Fig. 170, which not only gives sectional views of the clutch case and clutch release members but also depicts the appearance of the clutch assembly and shows the principal parts of the clutch when that unit is dismantled.

Another popular form of clutch is the three-plate type. That used on the Mack A. C. trucks is shown in section at Fig. 171, and it will be observed that it is very simple in construction.

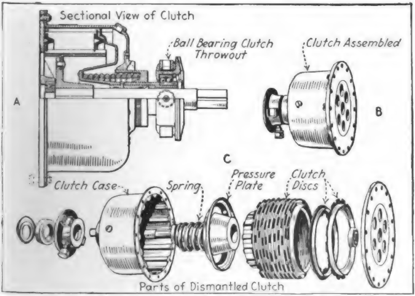

Sectional View of Clutch
Ball Bearing Clutch Throwout
Clutch Assembled
A
B
C
Clutch Case
Spring
Pressure Plate
Clutch Discs
Parts of Dismantled Clutch

Fig. 170—Sectional View of Hele-Shaw Clutch at A, External View of the Clutch Unit at B, and How Parts of the Clutch Look When It is Dismantled at C.

One face of the flywheel acts as a clutching surface and a floating disc is clamped between the flywheel and a spring pressed plate also driven by the flywheel so that it transmits the engine power to the shaft leading to the change speed gearing to which it is keyed and with which it must turn. The coil springs used to maintain the frictional driving pressure are short and are set in pockets spaced equidistant around the clutch cover plate. The clutch is released by a series of simple levers which make it possible to overcome the high spring pressure without any great exertion on the driver's part. When it is desired to release the clutch, the lever actuating sleeve is pushed back and the levers move the plate against which the clutch springs bear so that the driven disc is no longer clamped between the two driving faces.

Another popular form of three-plate clutch of Borg and Beck manufacture is shown installed in connection with a unit power plant at Fig. 172. In this design the driven plate is clamped between the flywheel face and a floating disc, but the driving pressure is obtained by a single coil spring and a series of bell crank levers.

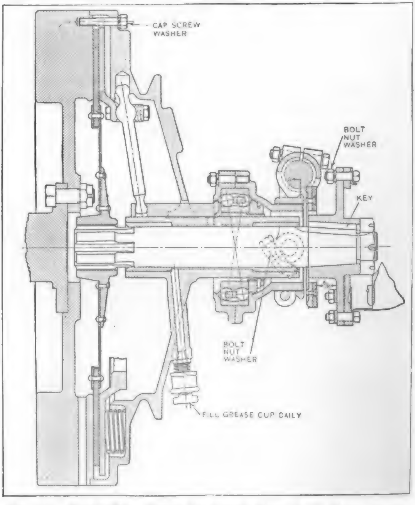

CAP SCREW
WASHER
BOLT
NUT
WASHER
KEY
BOLT
NUT
WASHER
FILL GREASE CUP DAILY

Fig. 171.—Single-Plate Clutch Used with Mack A. C. Motor Trucks.

Why Change-Speed Gearing is Necessary.—Those who are familiar with steam or electricity as sources of power for motor vehicles may not understand the necessity for the change-speed gearing which is such an essential component of the automobile propelled by internal combustion motors. In explaining the reason for the use of the clutch it has been demonstrated that steam or electric motors were very flexible and that their speed and consequently the power derived from them could be varied directly by regulating the amount of energy supplied from the steam boiler or the electric battery, as the case might be.

If, for example, we compare the steam motor with the explosive engine it will be evident that the power is produced in the former by the pressure of steam admitted to the cylinders as well as the quantity and the speed of rotation. When the engine is running slowly and a certain amount of power is needed more steam can be supplied the cylinders and practically the same power obtained as though the steam pressure was reduced and the engine speed increased. The internal combustion motor is flexible to a certain degree, providing that it is operating under conditions which are favorable to accelerating the motor speed by admitting more gas to the cylinders. There is an arbitrary limit, however, to the power capacity or the mean effective pressure of the explosion, and beyond a certain point it is not possible to increase the power by supplying vapor having a higher pressure as is possible with a steam engine.

In an explosive motor we can increase the power after the maximum throttle opening has been reached only by augmenting the number of revolutions. Whereas, it is possible to gear a steam engine or an electric motor directly to the driving wheels, it is not possible to do this with a gasoline engine, and some form of gearing must be introduced between the motor and the driving wheels in order that the speed of one relative to the other may be changed as desired and the engine crankshaft turned at speeds best adapted to produce the power required, and to allow the rear wheels to turn at speeds dictated by the condition of the roads or the gradients on which the truck is operated.

It is customary in all automobiles of the gasoline-burning type, where combustion takes place directly in the cylinders, to interpose change-speed gearing which will give two or more ratios of speed between the engine and the road wheels. As it is not possible to reverse the automobile engine utilized in conventional cars, it is necessary to add a set of gears to the gearset to give the wheels a reverse motion when it is desired to back the conveyance.

Many methods of varying the ratio of speed between the engine and traction members have been evolved, but few speed-changing mechanisms have survived. At the present time the majority of automobile makers employ sliding gear transmissions which are almost invariably of the selective type. But one maker provides two forward speeds and a reverse motion by using planetary gearing.

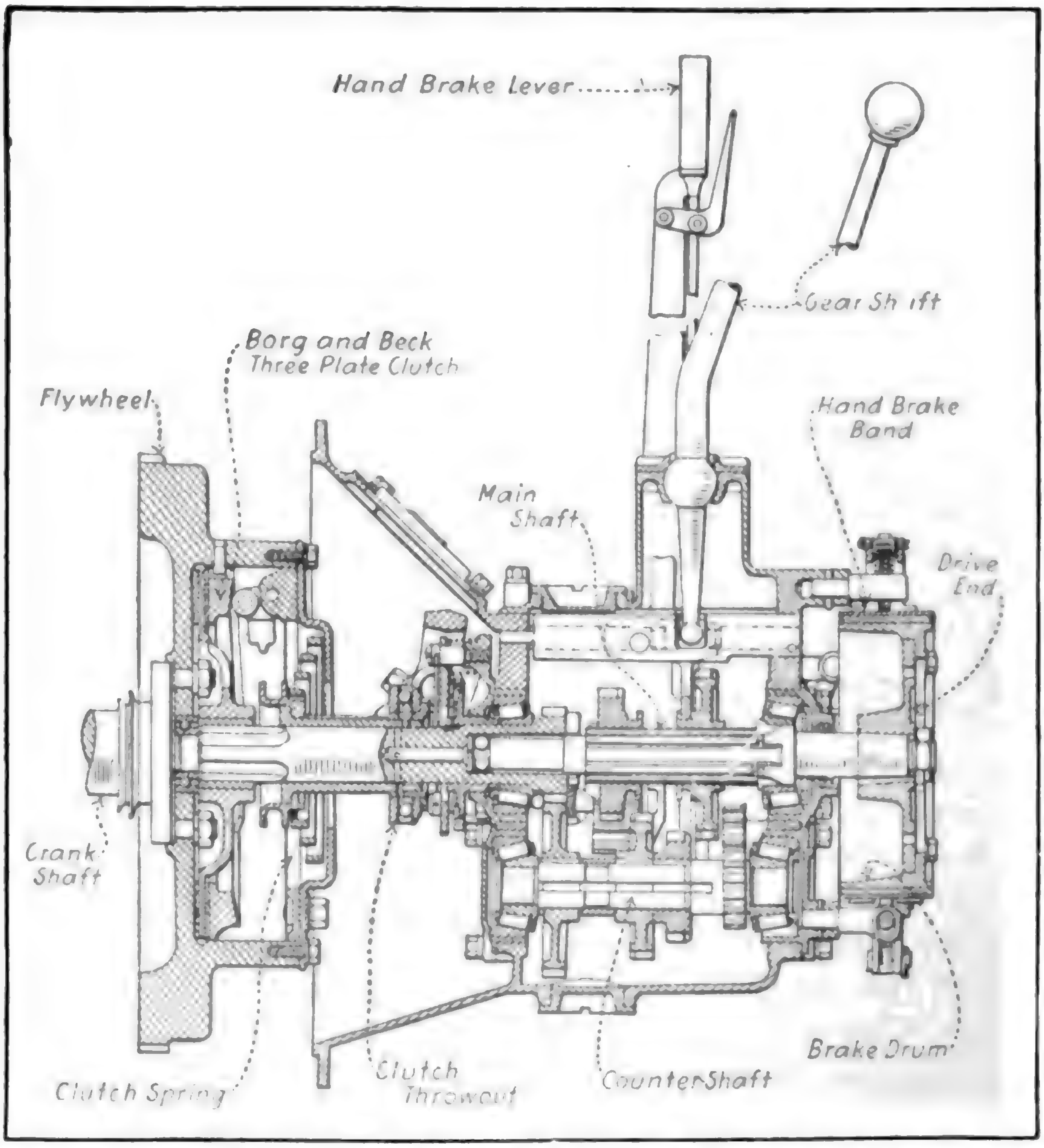

Hand Brake Lever
Gear Shift
Borg and Beck Three Plate Clutch
Flywheel
Hand Brake Band
Main Shaft
Drive End
Crank Shaft
Brake Drum
Clutch Spring
Clutch Throwout
CounterShaft

Fig. 172—Typical Gearset and Clutch Assembly Showing Borg and Beck Three-Plate Clutch and Three Sliding Gear Selective Gearset

Selective Change-Speed Gearing.—With but few exceptions, practically all motor trucks are equipped with change-speed gearing in which sliding gears carried on a main shaft are moved into engagement with fixed gears on a countershaft beneath or at the side of the main shaft. The gearset may provide either three or four forward speeds, depending upon the capacity of the truck to which it is fitted. The heavier trucks have four-speed gearboxes, while practically all light and medium capacity vehicles are equipped with three-speed gearboxes. There are various ways of installing the change-speed gearing. When a unit power plant is used it forms a part of that assembly and is bolted to the engine or clutch case. In trucks of long wheel base, the change-speed gearing is often mounted as an independent member amidships.

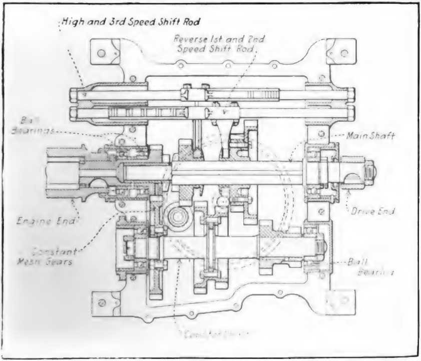

High and 3rd Speed Shift Rod
Reverse 1st and 2nd Speed Shift Rod
Ball Bearings
Main Shaft
Drive End
Engine End
Constant Mesh Gears
Ball Bearing
Countershaft

Fig. 173.—Plan View of Riker Four-Speed Gearset. A Good Example of Modern Design.

A three-speed gearbox, designed for installation with a unit power plant, is shown at Fig. 172, while the Riker four-speed gearset, which is a good example of modern design when the gearbox is mounted independently of the engine, as shown at Fig. 173. This difference in construction when four-speed gearboxes are used is also depicted at Fig. 174. That at A is in-

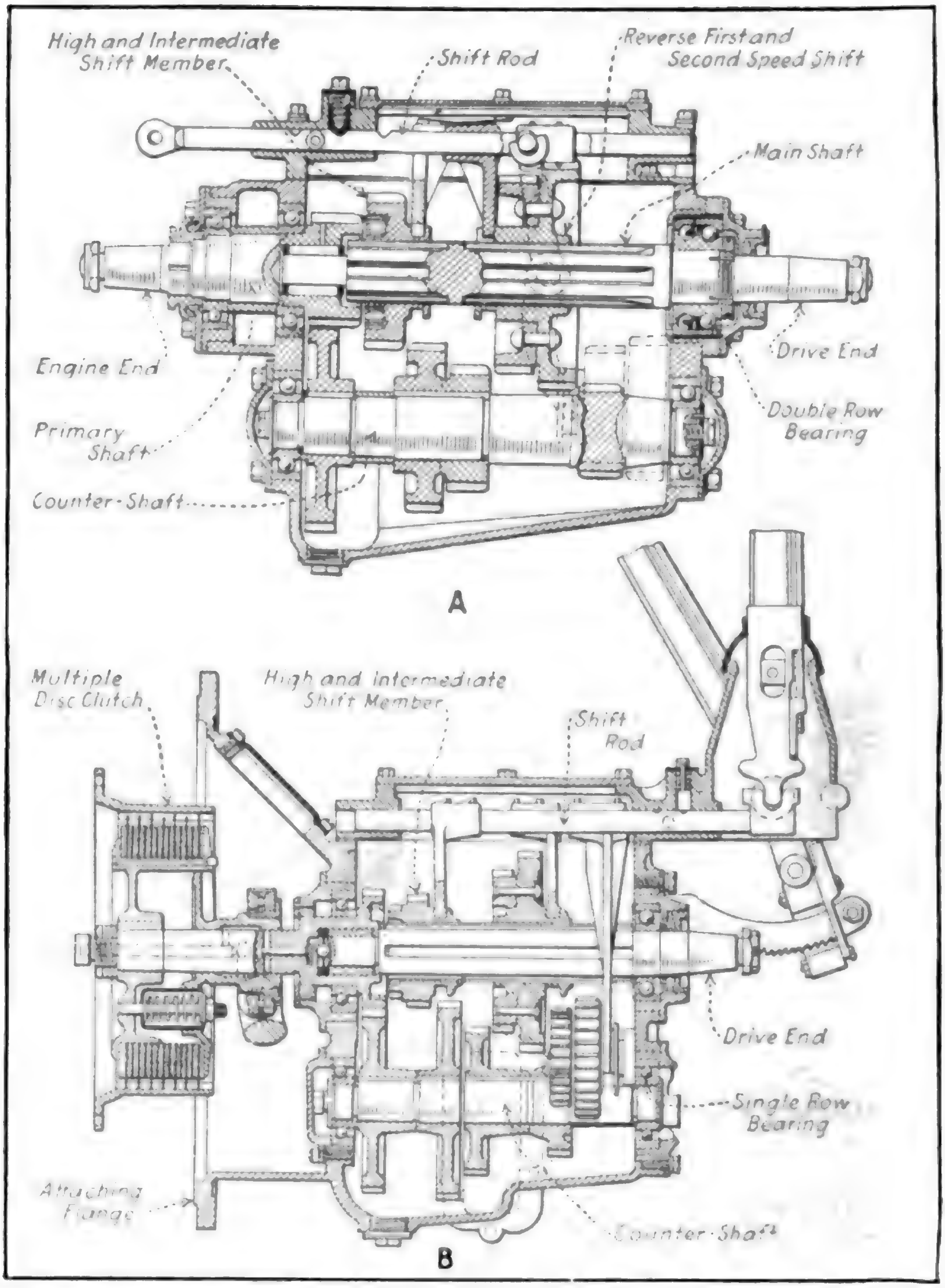

High and Intermediate Shift Member
Shift Rod
Reverse First and Second Speed Shift
Main Shaft
Engine End
Drive End
Double Row Bearing
Primary Shaft
Counter-Shaft
A
Multiple Disc Clutch
High and Intermediate Shift Member
Shift Rod
Drive End
Single Row Bearing
Attaching Flange
Counter-Shaft
B

Fig. 174.—Types of Four-Speed Selective Gearsets. A—Type for Independent Placing in Frame. B—Combined with Multiple Dry Plate Clutch for Unit Power Plant.

tended for independent placing in the frame, while that at B has a bell housing for bolting to the engine crankcase. It will be apparent that practically the only difference in construction between a three-speed and a four-speed gearbox is in the number of gears used. The countershaft of the latter usually carries one more gear than the three-speed form, while one of the shifting gear members carried on the splined main shaft is a double gear.

The selective system is the best form, because any desired gear ratio may be obtained without moving the sliding member through other gear ratios, with the exception of the member serving for low speed and reverse, which sometimes must be moved through the low speed position before it can engage the reverse gears. In most gearboxes, however, a separate idler gear member may be brought into engagement to secure a reverse ratio. In practically all cases the shafts of the change-speed gearing are mounted on anti-friction bearings of the ball or roller type in order to serve power. The shafts and gears are made of high tensile strength alloy steel and are kept in rigid alignment by substantial gearboxes of aluminum, bronze or malleable cast iron. In trucks where weight saving is not of as much importance as in passenger cars, a considerably wider use is made of cast iron for change-speed gearcases. In opera-

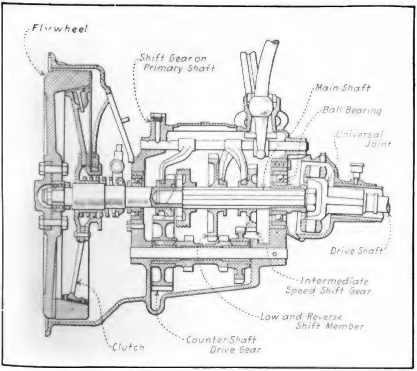

Flywheel
Shift Gear on Primary Shaft
Main Shaft
Ball Bearing
Universal Joint
Drive Shaft
Intermediate Speed Shift Gear
Low and Reverse Shift Member
Counter Shaft Drive Gear
Clutch

Fig. 175.—The Dodge Bros. Gearset as a Unique Feature of Having an Idle Countershaft When Direct Drive Gear is Engaged.

tion, the gears revolve in a constant bath of semi-fluid lubricant so that there is but little wear if the gear shifting is done intelligently.

The Dodge Change-Speed Gear.—The sliding gear used in the Dodge Brothers commercial cars is illustrated at Fig. 175, and is distinctive in design because when the direct drive clutch is engaged the countershaft does not revolve as it does in the conventional sliding gear form. In the more common construction, it will be observed that the countershaft is driven by a gear that is constantly in mesh with the clutch gear carried by the primary shaft of the gearset. It is apparent that no matter what gear ratio is used that the countershaft and the gears it carries must revolve all the time that the engine is driving the car or even when the gears are out of mesh and the engine running with the clutch engaged. In the Dodge construction, the countershaft drive gear engages with a sliding member which is moved

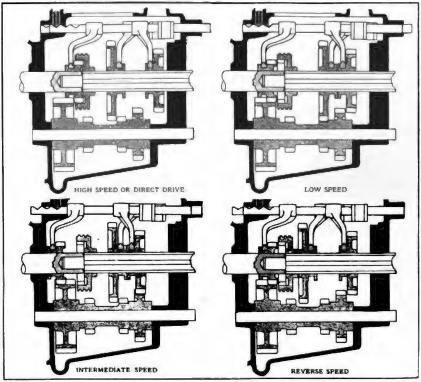
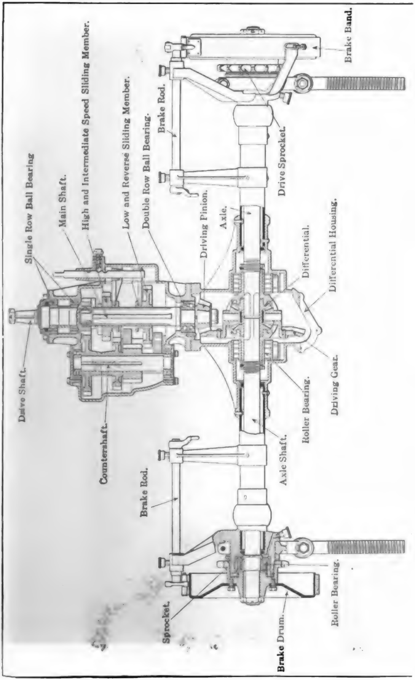


Fig. 176.—Views Detailing Position of Gear Shifting Members in the Dodge Bros. Transmission for Different Speed Ratios.

Change Speed Gear and Countershaft


Drive Shaft.
Single Row Ball Bearing
Main Shaft.
High and Intermediate Speed Sliding Member.
Low and Reverse Sliding Member.
Double Row Ball Bearing.
Brake Rod.
Driving Pinion.
Axle.
Drive Sprocket.
Brake Band.
Differential.
Differential Housing.
Driving Gear.
Roller Bearing.
Axle Shaft.
Countershaft.
Brake Rod.
Sprocket.
Brake Drum.
Roller Bearing.

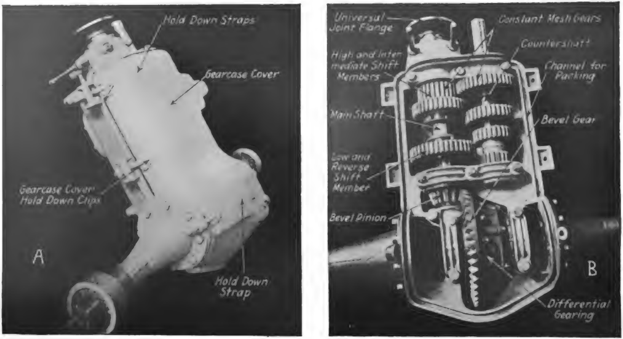

Hold Down Straps
Gearcase Cover
Gearcase Cover Hold Down Clips
A
Hold Down Strap
Universal Joint Flange
Constant Mesh Gears
Countershaft
High and Intermediate Shift Members
Channel for Packing
Main Shaft
Bevel Gear
Low and Reverse Shift Member
Bevel Pinion
B
Differential Gearing

Fig. 178.—Views of the Gearbox of the Mack A. C. Trucks. View at A Shows Transmission Assembly with Cover in Place. Illustration at B Shows Transmission Gears, Speed Changing Members and Differential Assembly as Exposed When the Cover is Removed.

to clutch the splined shaft when it is desired to engage the direct drive. Under this condition it must leave the teeth of the countershaft drive gear before it can clutch the internal teeth of the splined shaft drive member. The position of the different shift members when various gear ratios are in mesh are clearly shown in the sectional views at Fig. 176.

Combined Jackshaft and Gearbox.—When the transmission gear is used in a chain drive truck it is usually incorporated with the countershaft, as shown at Fig. 177. This means that the gearbox is a unit with the primary reduction gears and that it will remain in positive alignment with it. The differential mechanism is always carried in the countershaft housing and the drive is by shafts to the sprockets at the outer end, from which chains run to larger sprockets attached to the wheels. The rear axle is a simple steel bar or forging that does not revolve but which carries bearings on which the wheels rotate. A typical change-speed gearing and countershaft assembly, such as used on the Mack A. C. truck, is shown at Fig. 178. The view at A shows the gearbox assembly complete and the method of holding the gearcase halves together by straps having retention bolts at the ends. The interior construction and arrangement of the gears is clearly outlined at B, which shows the countershaft assembly when the gearcase cover is removed to expose the change-speed differential and driving gear elements.

The White Clutch and Gearbox.—The four-speed gearbox of the White truck, also the clutch and its control pedal, are shown at Fig. 179. The clutch is a three-plate type, the driven plate being clamped between the flywheel driving face and a movable member having one flat face that contacts with the driven plate and a beveled face against which the spring pressed wedge members bear. A threaded ring, which also has a beveled face, serves as an abutment for the wedges. This can be adjusted by screwing in to compensate for depreciation of the clutch friction facing material. When the spring is compressed, the wedges are withdrawn from between the bevel faces, and the friction fabric faced driven plate "floats" between the clamping plate and the flywheel face, thus allowing the engine to turn without driving the main shaft of the gearbox.

The power from the clutch is delivered to the transmission through the main drive gear or clutch gear shaft. The power transmitted through the transmission is finally delivered to the rear drive system; that is, the universal joints, propeller shaft and rear axle, through the main drive or "splined" shaft, to the rear end of which the universal joint is attached. The main drive shaft, the clutch shaft and the countershaft are all carried upon annular ball bearings. The reverse idler shaft is carried in the lower half of the transmission case and is stationary.

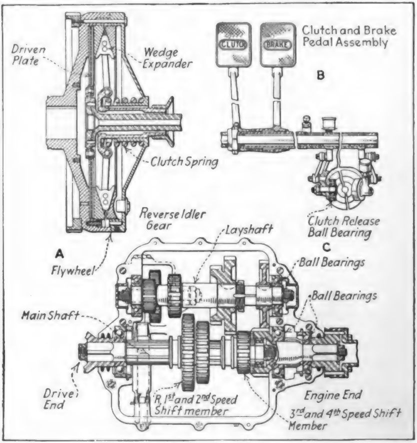

Driven Plate
Wedge Expander
Clutch Spring
CLUTCH
BRAKE
Clutch and Brake Pedal Assembly
B
Reverse Idler Gear
Layshaft
Clutch Release Ball Bearing
C
A
Flywheel
Ball Bearings
Ball Bearings
Main Shaft
Drive End
R 1st and 2nd Speed Shift member
Engine End
3rd and 4th Speed Shift Member

Fig. 179.—The Clutch Used in White Motor Trucks Outlined at A. B Shows the Clutch Shift Mechanism Using Ball Bearings for Shift Rolls. View of the Gearbox at C Clearly Outlines Arrangement of Parts.

The entire transmission gearcase is made up in four units: The upper half, which supports the entire case; the lower half, which is bolted to the upper half; the cap, which holds the gearshift lever shaft in place and carries the gearshift quadrant, and the transmission cover plate, which not only closes the opening

by Google

in the top of the transmission case, upper half, but also carries the tire pump. All of these parts of the transmission case are made from cast iron.

Operation of Transmission.—The operation of the transmission cannot be clearly understood until one has in mind the location of the various gears and their names. The main drive or clutch gear is located in the front end of the transmission and receives the power direct from the clutch shaft. It drives the countershaft driven or back gear, with which it is constantly in mesh, hence the common designation of these two gears as the "constant mesh" gears. The clutch gear is sometimes called the "spigot" gear, because the front end of the splined shaft is supported by a "spigot" bearing in its interior. There are four gears on the countershaft besides the constant mesh gear. The largest of the four is the fourth speed drive gear, the next is the second speed gear, then comes the low speed gear and, lastly, the reverse pinion. There are two sliding members on the main or splined shaft; one of these is a single small gear member and is used for the direct drive connection on third speed and for meshing with the largest gear of the transmission countershaft for obtaining the geared-up high speed. The other member has two gears that move in unison, and with these the second, low and reverse speeds are obtained.

There are four forward speeds, the direct drive being the third speed, the fourth or highest speed is "stepped up" and is intended for use on the level when lightly loaded or on grades. The various gear positions to obtain the changes of gear ratio are clearly outlined at Fig. 180, the gear through which the power passes being indicated by arrows. When the gears are engaged to secure the highest speed ratio, the arrangement of parts is as shown at D. The single or high-speed sliding gear is pushed back until it meshes with the fourth speed gear of the countershaft. The drive is then from the main drive gear to the countershaft and from that member to the sliding gear member on the splined shaft. There is considerable difference in size between these members, so the splined shaft turns faster than the countershaft.

On the direct drive or third-speed position the single or high-speed sliding gear is moved forward until the teeth on its face engage with the projecting teeth on the clutch gear, this locking the splined shaft to the clutch shaft and permitting the trans-

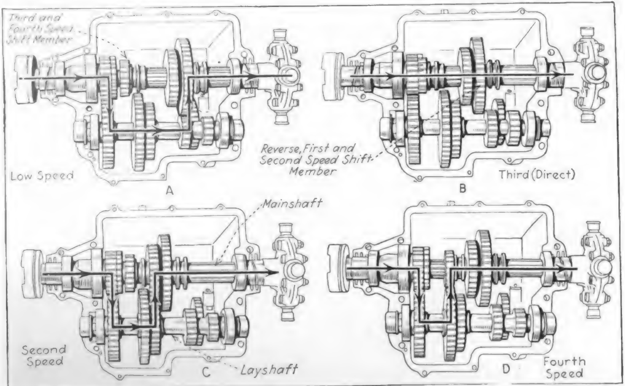

Third and Fourth Speed Shift Member
Low Speed
A
Reverse, First and Second Speed Shift Member
B
Third (Direct)
Mainshaft
Second Speed
C
Layshaft
D
Fourth Speed

Fig. 180.—How the Power is Transmitted Through Various Gears to Obtain Different Speed Ratios on White Motor Truck.

mission of power directly from the clutch to the rear universal joint without passing through any of the countershaft gears.

In the second speed position the double sliding gear is moved forward from the neutral position until the front gear of the pair is in mesh with the second speed gear mounted on the countershaft. The power then follows the course of the arrows as shown at C.

The double gear is moved to the rear from its neutral position in order to engage the low-speed countershaft gear. When in this position the power is transmitted from the main drive or clutch gear to the countershaft driven or back gear, through the countershaft to the low-speed gear, thence through the larger of the double gears to the main drive or "splined" shaft, and thence to the rear wheels.

The reverse is operated by means of a double shift in the gearbox, although it merely means moving the gear shift lever from low-speed position to reverse speed position, which is simply a movement of the lever farther forward in its quadrant. To engage the reverse gear, starting from neutral, it is necessary to first pass through the low or first-speed position, and vice versa. It is necessary to go through the low-speed gear when returning from reverse to the neutral position.

Starting with the double gear in the low-speed position, it is moved farther to the rear to engage the reverse speed. To engage this reverse speed, it is necessary not only to shift the double gear to the rear, out of mesh with the low-speed gear, but also to slide the reverse idler gear, mounted upon the stationary reverse idler gear shaft, to the rear. The latter motion is accomplished by the use of a reverse shifted lever carried in the lower half of the transmission case and carried upon the reverse shifter lever shaft, which is fixed in the case. The reverse idler gear is drawn out of mesh, when the gears are returned to first speed or to neutral, by means of a spring which operates on the reverse shifter lever.

When the power is transmitted through the reverse gears, it will be from the clutch or main drive gear to the countershaft driven or back gear, through the countershaft to the countershaft reverse gear, thence through the reverse idler gear to the larger double gear. From these it is transmitted through the main drive or "splined" shaft to the rear wheels, but as the idler gear has been introduced into the system, the main drive shaft will now rotate in the opposite direction to which it does normally, and thus give the reverse speed.

Individual Clutch Transmission.—A form of gearset which combines the good features of the planetary type in that the driving gears are always in mesh and which can be provided with any desired number of speed ratios is known as the individual clutch type. In gearsets of this form one set of gears is carried by the countershaft and is fixed thereto, while another set of gears, with which these members mesh, revolve idly on the main driving shaft.

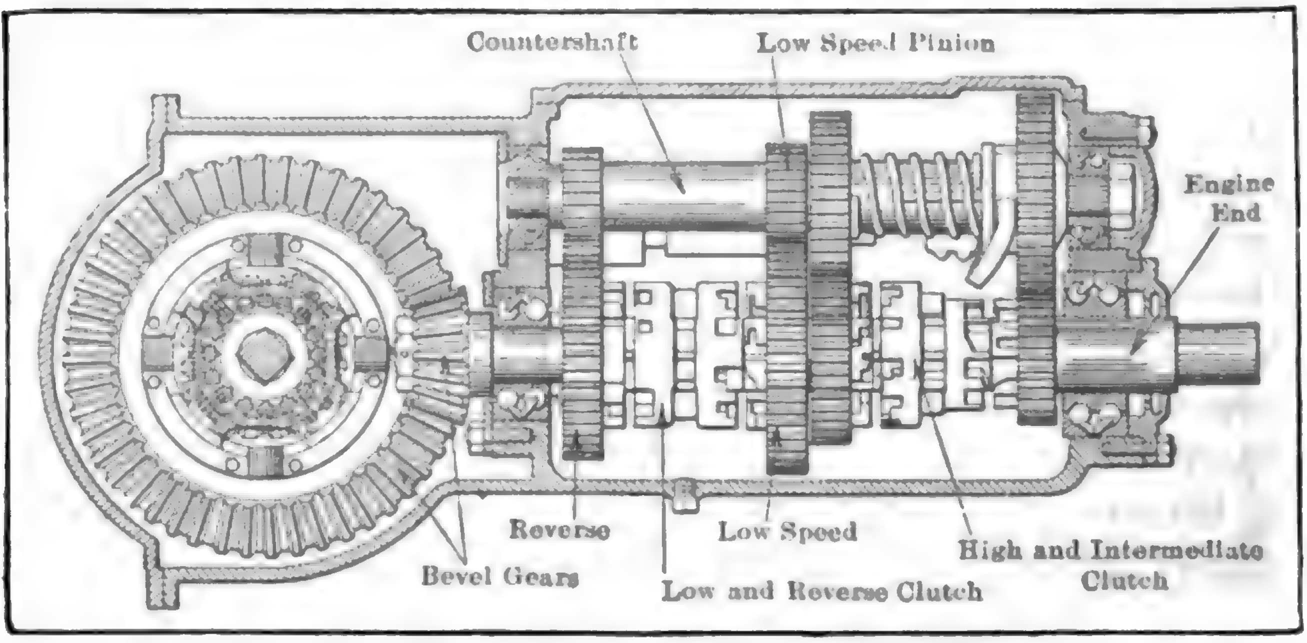


Fig. 181.—Part Sectional View of Cotta Individual Clutch Gearset Designed for Motor Truck Service.

A transmission of this type, which has been applied successfully in motor truck design, is shown at Fig. 181. In this the power is delivered to a main shaft, which is supported on ball bearings and which carries a bevel pinion engaged with a bevel gear for driving the wheels at the rear end. The gears mounted on the main shaft are normally free to revolve independently from the shaft unless they are clutched to it by sliding positive jaw clutch members driven by the main shaft. Any desired speed ratio may be selected by engaging the gear desired by means of the clutch carried at its side, thus causing it to turn with the shaft.

When the clutches are placed as shown in illustration, the gears are neutral and the driving shaft turns without producing movement of the bevel driving gears. If it is desired to engage the low speed, the low and reverse clutch member is moved toward the front end of the gearset until it clutches the low-speed gear to the main shaft. The power of the engine is then applied to the countershaft through the constant mesh gears at the extreme front end of the gearset, and as the main shaft is made in two pieces, the end of one member telescoping into the portion that carries the driving connection to the engine, the drive is back from the countershaft low-speed pinion to the big gear, which has been clutched to the main shaft and which causes it to turn slower than the driving member attached to the engine.

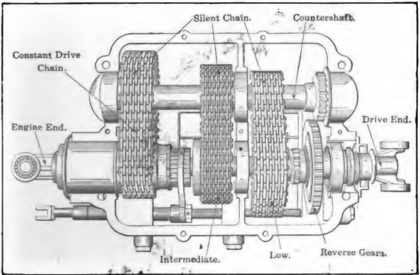


Fig. 182.—Individual Clutch Transmission of English Design Using Silent Chain Connection Between Main and Countershafts for Forward Speeds and Sliding Spur Gears for Reverse Action.

To obtain a reverse ratio the low and reverse clutch is moved to the back end of the transmission and the reverse gear is locked to the main shaft. To obtain direct forward drive the high and intermediate clutch member is pushed forward until it engages the teeth on the side of the constant mesh gear. This operation locks both portions of the main shaft together and causes that part to which the bevel driving pinion is secured to turn at the same speed of rotation as the driving end, which is joined to the engine. The clutches are arranged in such a manner that only one can be used at a time, and in addition to the positive clutches carried in the gear case some form of master

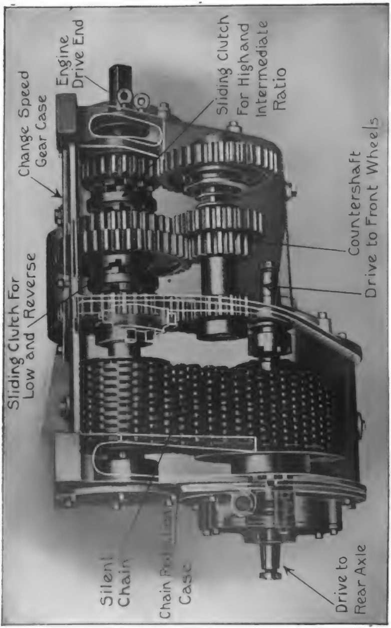

Change Speed Gear Case
Engine Drive End
Sliding Clutch For High and Intermediate Ratio
Countershaft Drive to Front Wheels
Sliding Clutch For Low and Reverse
Silent Chain
Chain Reduction Case
Drive to Rear Axle

Fig. 183.—Special Gearset with Integral Reduction Gearing for Four-Wheel Drive Truck.

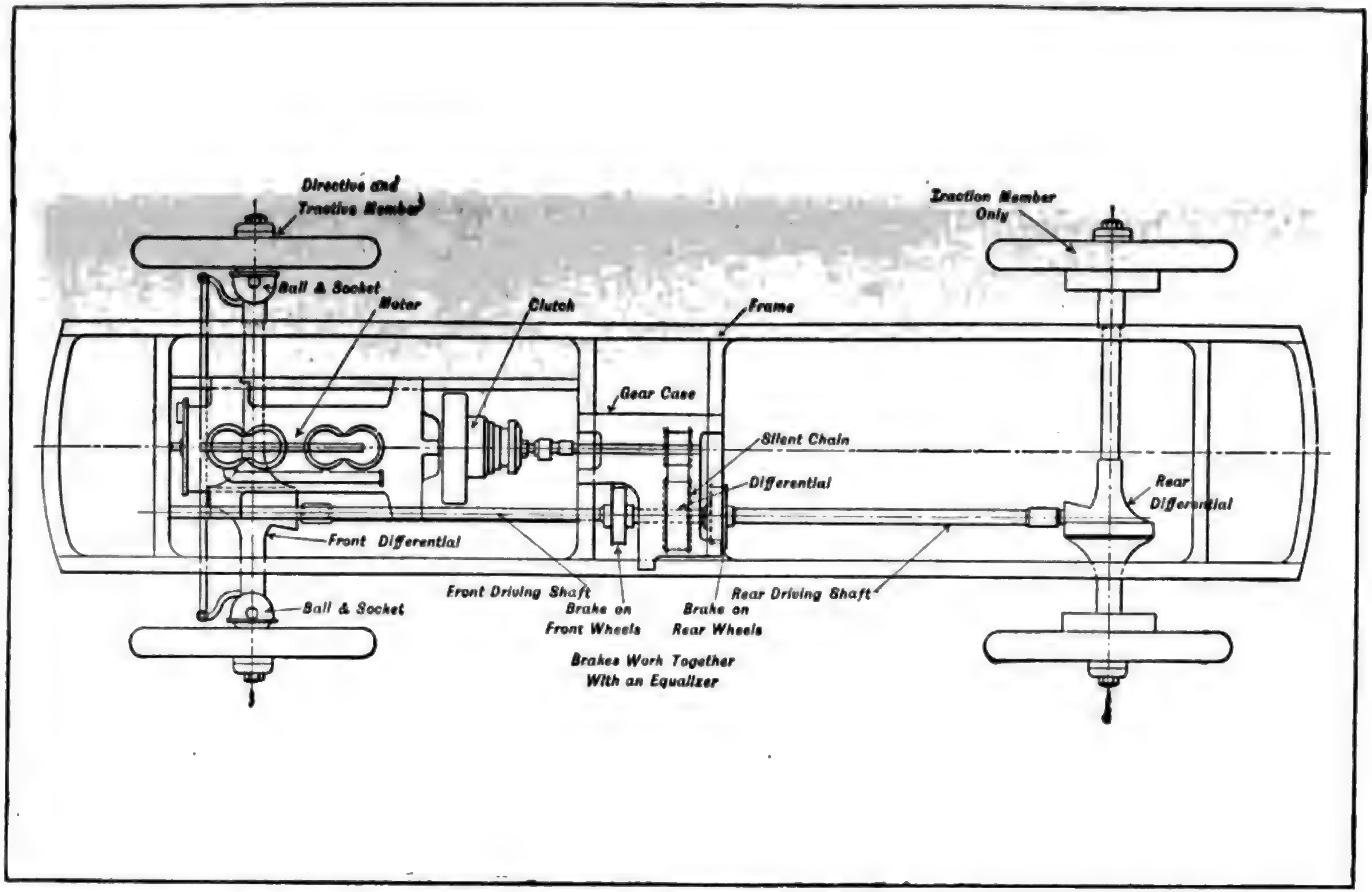

Directive and Tractive Member
Ball & Socket
Motor
Clutch
Frame
Traction Member Only
Gear Case
Silent Chain
Differential
Rear Differential
Front Differential
Front Driving Shaft
Brake on Front Wheels
Brake on Rear Wheels
Rear Driving Shaft
Ball & Socket
Brakes Work Together With an Equalizer

Fig. 184.—Plan View of Chassis of Four-Wheel Drive Truck Showing Location of Gearbox.

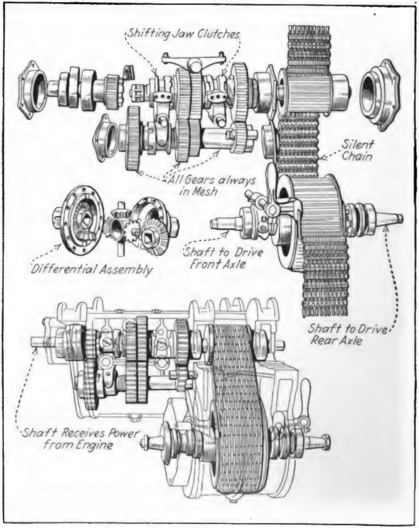

Shifting Jaw Clutches
Silent Chain
All Gears always in Mesh
Differential Assembly
Shaft to Drive Front Axle
Shaft to Drive Rear Axle
Shaft Receives Power from Engine

Fig. 185.—Illustration Showing Appearance of Important Components of Transmission Gearing of Four-Wheel Drive Truck as They Appear When Removed from the Gear Case.

clutch, which is invariably of the friction type, must be provided between the power plant and the gearset.

There is some tendency to apply the silent chain to positive individual clutch types of transmissions developed for bus use in England instead of utilizing direct gear connection. The application of silent chains to a gearbox is shown at Fig. 182, but this method of construction has never become general.

Transmission Gear for Four-Wheel Drive.—When a four-wheel drive system is employed it is necessary to use a radically different form of gearset from that commonly employed in cars where a single drive shaft goes to a rear axle to which the tractive members are attached. A gearset of this type is clearly outlined at Fig. 183, and its actual application to a four-wheel drive chassis is shown at Fig. 184. The change-speed gearing is of the individual clutch type and provides three forward speeds and a reverse ratio by means of sliding jaw clutches which lock gears that are always in mesh with each other securely to the drive shaft. The main driving shaft is extended through a supplementary casing attached to that containing change-speed mechanism. A silent chain serves to transmit power from a suitable sprocket on the driving shaft to another member placed on the driven shaft below it. This driven shaft extends through the casing at both ends and the drive to the front and rear axles is by means of the usual propeller shafts and universal joints from the front and rear ends of the chain-reduction case, respectively. In the chassis shown at Fig. 184, the axles are different. The rear axle is a conventional form and the wheels are utilized for tractive purposes only. The front axle is a special construction, in which the wheels are driven by ball and socket joints which permit of their inclination to steer the vehicle without interfering with the power-transmission functions. The parts of a typical positive clutch gearbox are shown at Fig. 185, which shows an assembly dismantled. The position of clutches for different gear ratios are clearly shown at Fig. 186.

Gear Reductions and Engine-to-Wheel Ratios.—Since the transmission is a means of changing driving wheel tractive effort, the gears acting as levers, the leverage is in proportion to the tooth ratios of any pair. Thus, if one gear has 20 teeth and the one driving it five teeth the ratio is 20 ÷ 5, or 4 to 1. In one typical transmission the ratios are as follows:

First speed	6.10 to 1
Second speed	3.55 to 1
Third speed	2.02 to 1
Fourth speed	1.22 to 1
Reverse	6.46 to 1

However, in the drive from the transmission to the wheels there is further reduction, the first one by the bevel gears in

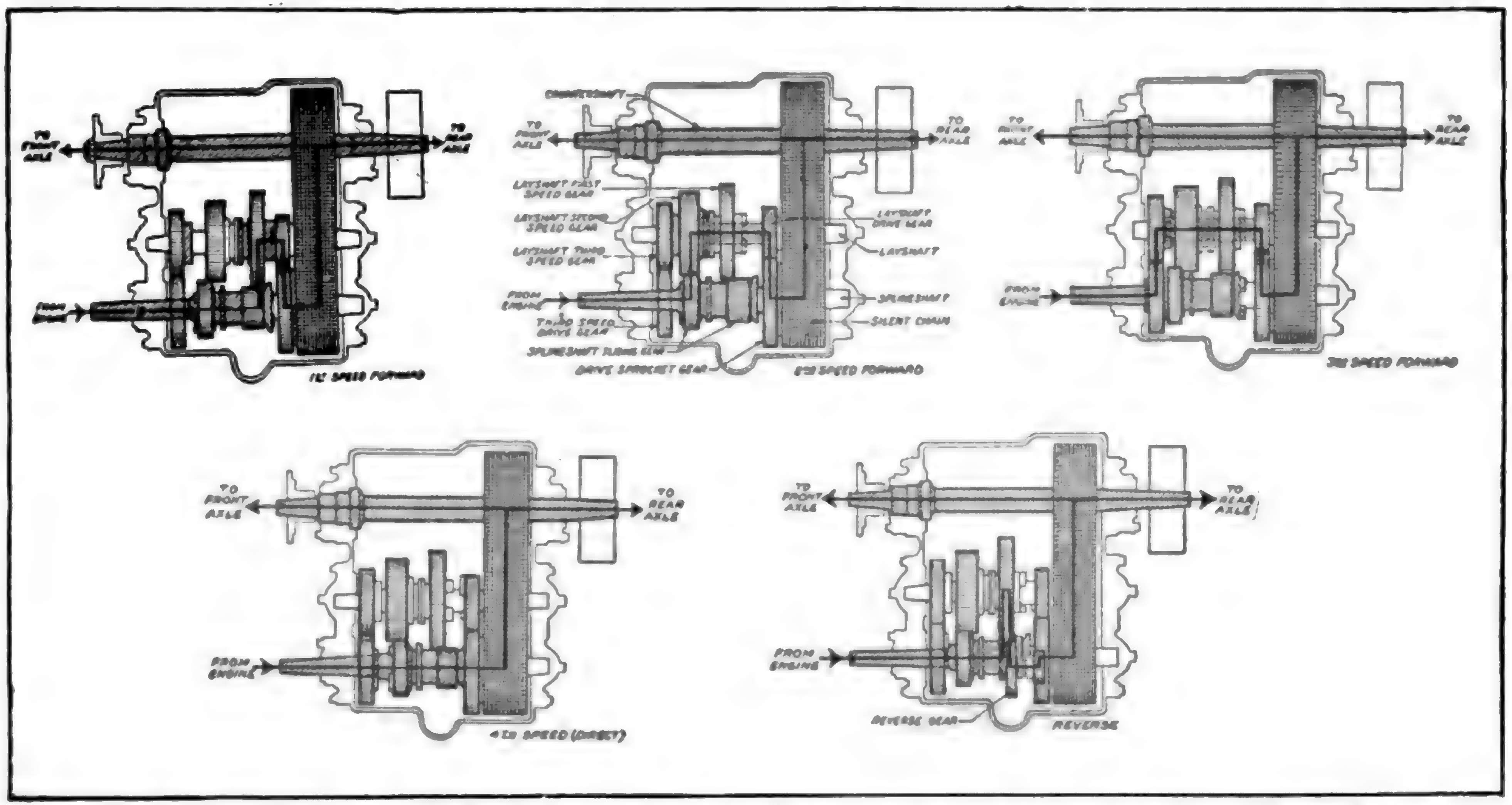

TO FRONT AXLE
TO REAR AXLE
FROM ENGINE
1ST SPEED FORWARD
COUNTERSHAFT
LAYSHAFT FIRST SPEED GEAR
LAYSHAFT SECOND SPEED GEAR
LAYSHAFT THIRD SPEED GEAR
THIRD SPEED DRIVE GEAR
SPLINESHAFT SLIDING GEAR
DRIVE SPROCKET GEAR
LAYSHAFT DRIVE GEAR
LAYSHAFT
SPLINESHAFT
SILENT CHAIN
2ND SPEED FORWARD
3RD SPEED FORWARD
4TH SPEED (DIRECT)
REVERSE GEAR
REVERSE

Fig. 186.—Showing How Various Speed Ratios are Obtained in a Gearbox Used on Four-Wheel Drive Truck.

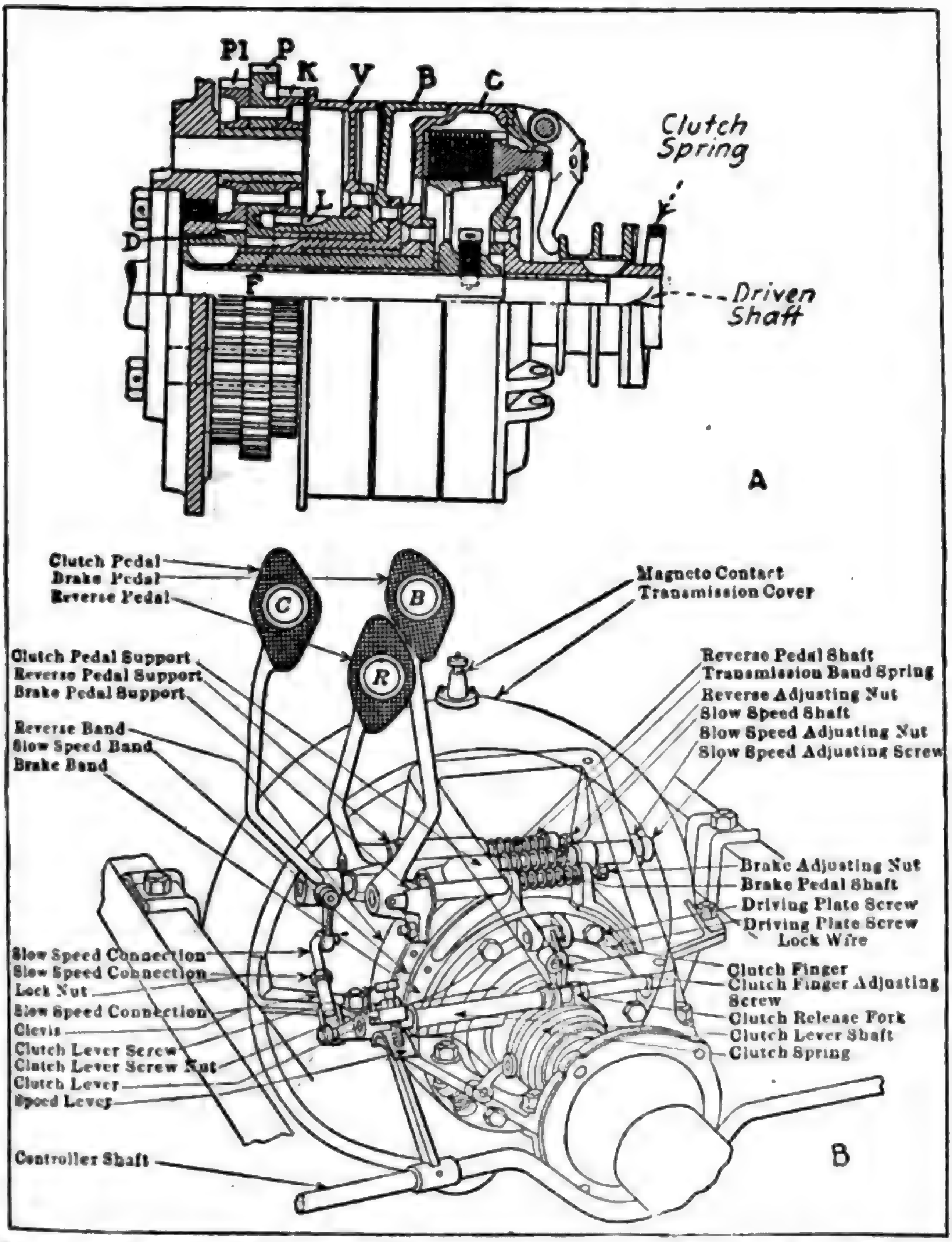

Pl
P
K
V
B
C
Clutch Spring
D
L
F
Driven Shaft
A
Clutch Pedal
Brake Pedal
Reverse Pedal
C
B
R
Magneto Contact
Transmission Cover
Clutch Pedal Support
Reverse Pedal Support
Brake Pedal Support
Reverse Band
Slow Speed Band
Brake Band
Reverse Pedal Shaft
Transmission Band Spring
Reverse Adjusting Nut
Slow Speed Shaft
Slow Speed Adjusting Nut
Slow Speed Adjusting Screw
Brake Adjusting Nut
Brake Pedal Shaft
Driving Plate Screw
Driving Plate Screw Lock Wire
Slow Speed Connection
Slow Speed Connection
Lock Nut
Slow Speed Connection
Clevis
Clutch Lever Screw
Clutch Lever Screw Nut
Clutch Lever
Speed Lever
Clutch Finger
Clutch Finger Adjusting Screw
Clutch Release Fork
Clutch Lever Shaft
Clutch Spring
Controller Shaft
B

Fig. 187.—The Ford Planetary Transmission Shown at A and the Method of Installation in the Power Unit Outlined at B.

the axles, which is 27 to 15 or 1.8 to 1, and the second by the internal gear and pinion in the wheel drum. This is 54 to 14, or 3.86 to 1, making a total reduction in the axle of 1.8 by 3.86, or 6.95 to 1. In order to obtain the actual ratio of engine revolutions to wheel revolutions in the various speeds the factor 6.95 must be used in every case. Thus, when in first speed the total reduction, or ratio of engine revolutions to wheel revolutions, is

6.1 times 6.95, or 42.3 to 1. In second speed the total reduction is 3.55 times 6.95, or 24.7 to 1. In third the total reduction is 2.02 times 6.95, or 14.04 to 1. In fourth speed the total reduction is 1.22 times 6.95, or 8.48 to 1, and in reverse 6.46 times 6.95, or 44.9 to 1.

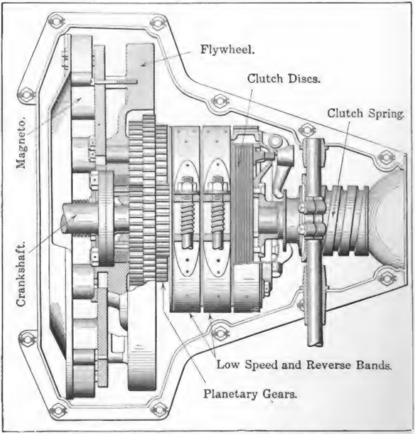

Flywheel.
Clutch Discs.
Clutch Spring.
Magneto.
Crankshaft.
Low Speed and Reverse Bands.
Planetary Gears.

Fig. 188.—Two-Speed and Reverse Planetary Gear Employed on Ford Automobiles as It Looks in Plan View.

Planetary Gearing of Ford Cars.—Planetary gearing has been very successful when properly designed and installed, and its chief disadvantage is that it is very difficult to provide more than two forward speeds and one reverse. For this reason it can only be adapted to light cars which have a surplus of power in the engine, or to light trucks, where it is not so essential that a large number of speed ratios be provided as in heavier vehicles. Such gearing is not efficient on low and reverse speeds, as considerable power is absorbed in gear and bearing friction, but when on the high speed or direct drive it is superior to any other form of change-speed gearing because the entire assembly is locked to the crankshaft, no gears are turning idly, and the weight of the gearing serves merely as an additional flywheel member.

The planetary transmission used on the Ford automobile is clearly outlined in part section at Fig. 187, A; the various adjustments and operating pedals are shown at Fig. 187, B, and a top view showing its location relative to the flywheel of the engine is shown at Fig. 188. The various adjustments are clearly outlined at Fig. 187, A. The operation is not difficult to understand. There are three groups of planetary pinions—P-1, P and K. These are riveted together, so they must turn at the same speed. Gear P-1 meshes with gear D, which is keyed to a driven member attached to the drum C. The drive gear F is mounted on the end of a bushing which is riveted to the brake drum D. The gear L is attached to the brake drum B. The clutch is a multiple disc type normally held in engagement by a coil spring.

Three brake bands are used for this transmission; the one that constricts around the drum C is the foot brake and acts to retard movements of the car, regardless of whether any of the other clutches are engaged. Tightening a band around drum B produces a slow speed. When the band is tightened around the drum V or that nearest the flywheel, a reverse motion is obtained. To apply either the slow speed or reverse band it is necessary to break the direct driving connection by releasing the clutch spring tension and allowing one set of clutch discs to move independently of the other set. One set of the clutch plates is carried by the clutch case C, which is keyed to gear D. The other set is carried by a clutch disc carrier which is supported by an extension of the engine crankshaft and prevented from turning by a setscrew passing through the clutch disc carrier hub into the shaft. The adjustment of the Ford direct drive clutch is a very simple operation, this consisting of releasing the setscrews in the clutchfingers by pulling out the split-pin that acts as a lock and turning in the adjusting-screws. The slow-speed adjustment is at the side of the gearcase, and may be reached without removing the cover plate of the transmission, which is necessary to adjust either the reverse clutch band or the foot brake band.

Ten-Speed Transmission.—That there is a natural tendency for a driver to speed a truck, when empty or on good roads, whether or not such a truck is built for high speeds, is the contention of the manufacturers of a ten-speed transmission. The truck on which this transmission is used is designed for a speed of 20 m.p.h., on high gear, with a crankshaft speed of only 1,000 r.p.m. It is this human equation element that has induced the makers to provide additional gear, for if an engine is not intended

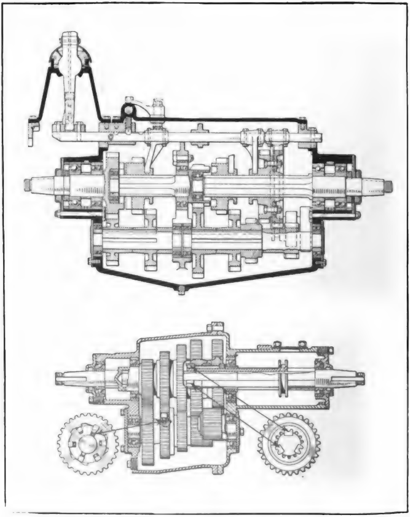


Fig. 188A.—Upper Illustration Shows Ten-Speed Gearbox. Lower View Shows Shifting Clutch Transmission.

for high speeds, an excessive speed may cause undue vibration or injure the moving parts, which facts the inexperienced driver often fails to consider.

This selective transmission, used on heavy trucks, has eight speeds forward and two backward. To effect the changes, a main shift-lever and an auxiliary lever are made use of, the former taking care of four speeds forward and one reverse. The auxiliary lever is used to double the reduction of any speed. Thus, if the speed is 14 m.p.h. and the auxiliary is brought into play, the speed at once drops to 7 m.p.h.; if the original speed is 10 m.p.h., an application of the auxiliary lever reduces it to 5. The normal portion of the gearing has the forward ratios of 1:1; 1:1.72; 1:3.20; 1:5.72; and reverse 1:6.12.

The transmission shown in Fig. 188A is manufactured by the G. A. Schacht Motor Truck Co., who are using it on their five-ton truck, and was described in Automotive Industries.

Shifting Clutch Transmission.—The Power-Rite principle of speed selection is claimed to make possible the changing of speeds without the usual jars and jerks. With gears constantly in mesh, there is no possibility of clashing, grinding or stripping —even under such severe strains as changing from a higher to a lower speed. These transmissions have long since passed the experimental stage and have proven their practicability in actual service. The superiorities which they have demonstrated in rigorous tests over a long period have won for them the approval of leading engineers in the motor car and motor industry. The sectional cut at Fig. 188A shows details of the one-way dog clutch, which gives full floating action to intermediate speeds on main shaft, thus eliminating "jerking" or "pitching" when changing from high to a lower speed. The cross section of main drive shaft shows the sliding-key construction which controls speed selection.

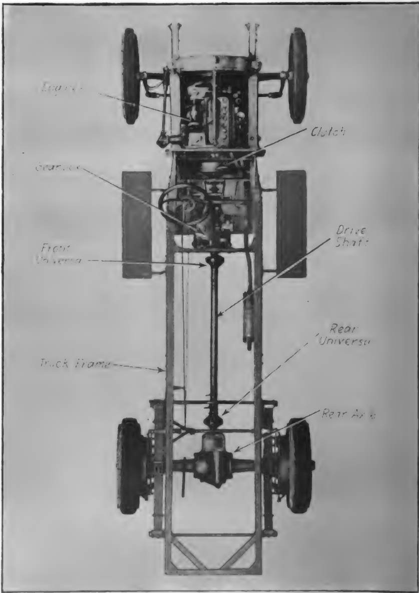

Engine
Clutch
Gearset
Drive Shaft
Front Universal
Rear Universal
Truck Frame
Rear Axle

Fig. 189.—Plan View of White Two-Ton Standard Chassis Showing Shaft Drive.

CHAPTER VII

MOTOR TRUCK DRIVE SYSTEMS

Power Transmission Methods—Countershaft Used With Chain Drive—Single Reduction Live Axle—Universal Joints—Purpose of Differential Gear—New Positive Drive Differential—Worm-Drive Gearing—Double Reduction Axles—Truck Axle with Planetary Secondary Reduction—Four-Wheel Drive and Steer System—Four-Wheel Drive Truck Details—Front-Wheel Drive System—Testing Motor Truck Drive System—A Six-Wheel Double Drive Axle Truck.

Power Transmission Methods.—There are two main methods of transmitting the power from the change-speed gearing to the rear wheels. The one commonly used at the present time is by a universally jointed propeller shaft to driving gears in the live rear axle. The chassis depicted at Fig. 189 is that of the White two-ton truck. The axle is not a simple form, because there are two sets of gears incorporated therein and a double reduction of speed before the power is delivered to the wheels. The chassis at Fig. 190 is that of the Model E two-ton truck manufactured by the International Harvester Company. This also employs shaft drive, but instead of the live axle forms such as used on the White truck, a double reduction axle in which the wheels revolve on a non-rotatable forging is used. As will be explained later, the wheels are driven by small spur pinions which engage with internal gears attached to the wheels. In both of these chassis the gearbox is an independent unit and is carried at a point in the frame approximately under the driver's seat.

The truck chassis shown in the plan view at Fig. 191 is that of the Packard worm drive truck. The change-speed gearing is located further back in the frame so that a shorter propeller shaft is used to transmit the power than is the case in either of the chassis previously described. In the worm gear axle there is but one set of reduction gears and a single reduction in speed.

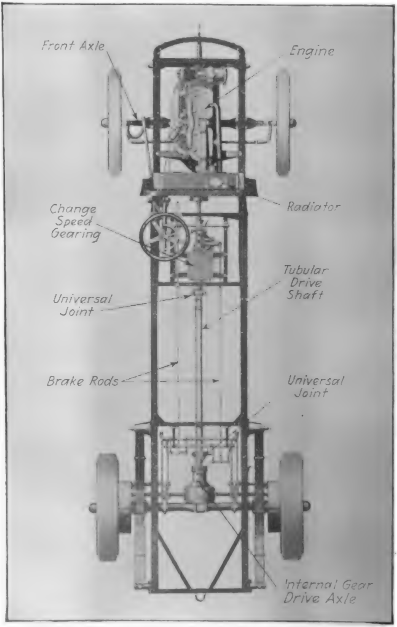

Front Axle
Engine
Radiator
Change Speed Gearing
Tubular Drive Shaft
Universal Joint
Brake Rods
Universal Joint
Internal Gear Drive Axle

Fig. 190.—Plan View of Chassis of the Model G International Harvester Truck, Showing Amidship Location of Change Speed Gearing and Drive by Hollow Shaft to Internal Gear Axle.

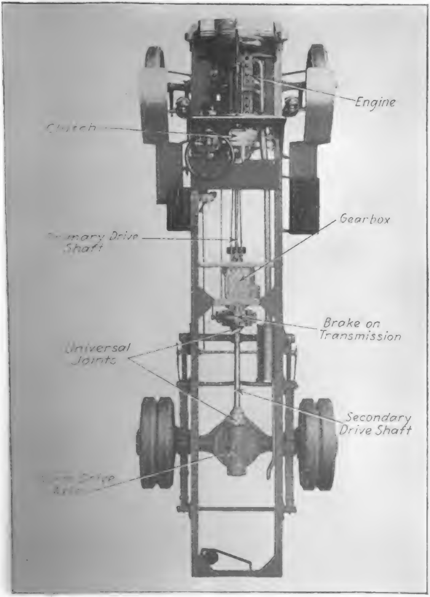

Engine
Clutch
Gearbox
Primary Drive Shaft
Brake on Transmission
Universal Joints
Secondary Drive Shaft
Worm Drive Axle

Fig. 191.—Plan View Showing Packard Motor Truck Chassis with Amidship Location of the Change Speed Gearing and Drive by Short Shaft to Worm Gear Axle.

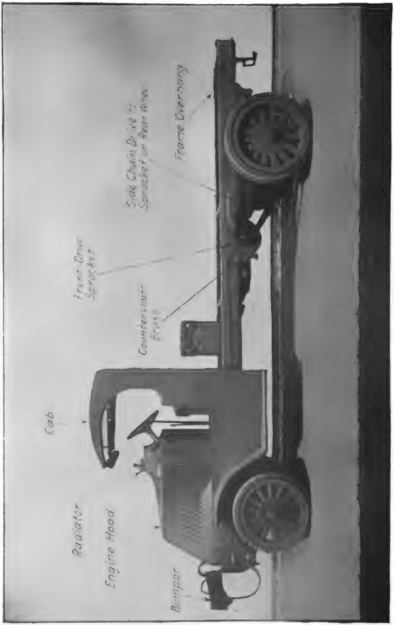

Bumper
Engine Hood
Radiator
Cab
Countershaft Brake
Front Drive Sprocket
Side Chain Drive to Sprocket on Rear Wheel
Frame Overhang

Fig. 192.—Side View of Mack A. C. Motor Truck Chassis Showing Drive from Countershaft by Means of Side Chains to Sprockets on the Rear Wheels.

The chassis depicted at Fig. 192 is the Mack A. C. type constructed for the Engineering Corps of the United States Army. In this view the application of side chain drive from small sprockets carried at each end of the jackshaft to others of large diameter on the rear wheels is clearly shown. Attention is also directed to the substantial frame construction of this truck. The advantage given for both chain and internal gear-driven trucks is that the power is applied near the wheel rim instead of at the hub, as is the case with the usual single reduction live axle and also in those double reduction forms where the primary and secondary reduction gearing are carried in the differential housing and the wheels are driven by shafts which extend from the differential to the wheel hub.

Countershaft Used With Chain Drive.—The countershaft or jackshaft, as it is often called, of the White five-ton truck is a distinctive construction because it has two reductions of speed in the jackshaft assembly and a still further reduction in the chain drive because of the varying diameters of the sprockets. The differential assembly at Fig. 193 shows how the two reductions of speed are obtained. The first one is between a pair of helically cut spur gears, one mounted above the other. The lower shaft carries the bevel pinion, which meshes with the ring gear that drives the differential mechanism. Shafts extending from the differential to the sprocket carriers deliver the power to the sprockets. A modification of this construction is employed in one of the live rear axles used on the model of this truck, as shown at Fig. 189.

Single Reduction Live Axles.—The construction of the simplest form of live axles of the non-floating type is well exemplified in that of the Ford Model T car which is shown at Fig. 194. The sectional view outlines clearly all parts. The driving or propeller shaft has the bevel pinion at its end to drive the ring gear attached to the differential. As this shaft is protected by a torque tube and revolves in bearings contained therein, but one universal joint is necessary, and that at the front end. Shafts extend from the differential gear to the rear wheel hubs. All shafts revolve on roller bearings of the Hyatt Flexible form, and it will be apparent that the entire weight of the rear end of the car must be carried by the bearings at the outer ends of the axles. The shafts not only transmit power, but also carry the weight of the rear end of the car.

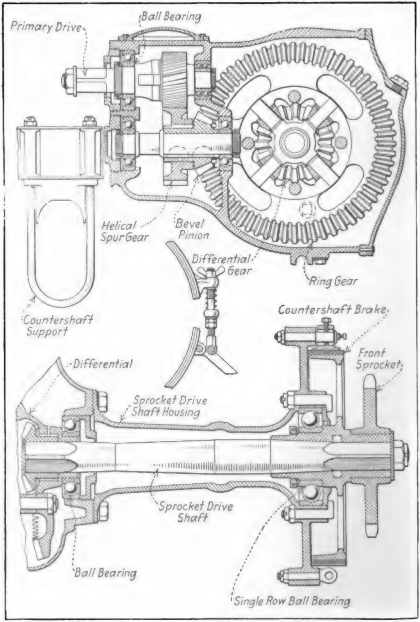

Primary Drive
Ball Bearing
Helical Spur Gear
Bevel Pinion
Differential Gear
Ring Gear
Countershaft Support
Countershaft Brake
Front Sprocket
Differential
Sprocket Drive Shaft Housing
Sprocket Drive Shaft
Ball Bearing
Single Row Ball Bearing

Fig. 193.—Sectional Views Outlining Construction of the Double Reduction Jack Shaft of Five-Ton Chain Drive White Models.

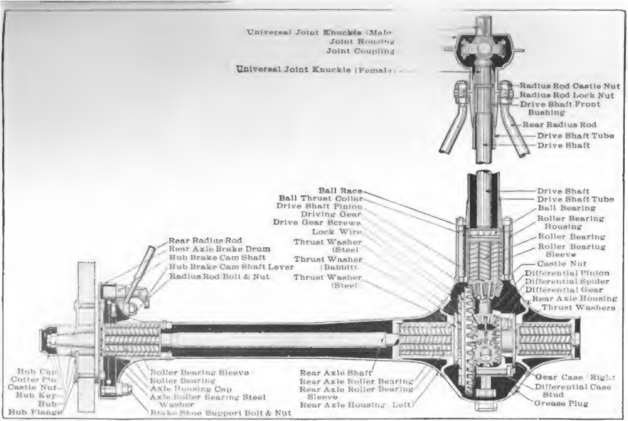

Universal Joint Knuckle (Male
Joint Housing
Joint Coupling
Universal Joint Knuckle (Female)
Radius Rod Castle Nut
Radius Rod Lock Nut
Drive Shaft Front Bushing
Rear Radius Rod
Drive Shaft Tube
Drive Shaft
Ball Race
Ball Thrust Collar
Drive Shaft Pinion
Driving Gear
Drive Gear Screws
Lock Wire
Thrust Washer (Steel
Thrust Washer (Babbitt
Thrust Washer (Steel
Drive Shaft
Drive Shaft Tube
Ball Bearing
Roller Bearing Housing
Roller Bearing
Roller Bearing Sleeve
Castle Nut
Differential Pinion
Differential Spider
Differential Gear
Rear Axle Housing
Thrust Washers
Rear Radius Rod
Rear Axle Brake Drum
Hub Brake Cam Shaft
Hub Brake Cam Shaft Lever
Radius Rod Bolt & Nut
Hub Cap
Cotter Pin
Castle Nut
Hub Key
Hub
Hub Flange
Roller Bearing Sleeve
Roller Bearing
Axle Housing Cap
Axle Roller Bearing Steel Washer
Brake Shoe Support Bolt & Nut
Rear Axle Shaft
Rear Axle Roller Bearing
Rear Axle Roller Bearing Sleeve
Rear Axle Housing (Left)
Gear Case (Right
Differential Case Stud
Grease Plug

Fig. 194.—Sectional View of Ford Model T Rear Axle Showing Drive Gears, Differential, Power Transmission Shafts and Supporting Bearings of the Hyatt Flexible Roller Form.

The live axle of some of the lighter models of White trucks is shown at Fig. 195, and this also is a form in which a single-speed reduction obtains. The drive shaft goes to a universal joint on a short pinion shaft. The bevel pinion that engages with the ring gear is supported by two large ball bearings of the single row form, between which it is placed. The drive to the rear wheel hub is by live axle shafts, but in this construction the shaft is not called upon to support the entire load on the wheel hub on account of the way that member is carried by the single row bearing which is installed in the axle shaft housing. The inner race of the ball bearing is clamped on the wheel hub and the outer race is supported by the housing. In this construction the axle shaft must act as a steadying member for the wheel and, while it is loaded to a greater extent than it would be if it was used only for transmitting power, it does not carry the same proportion of the rear end load that the live axles do in the constructions exemplified by the Ford axle.

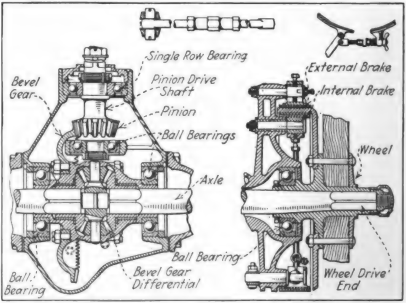

Single Row Bearing
Bevel Gear
Pinion Drive Shaft
Pinion
Ball Bearings
Axle
Ball Bearing
Bevel Gear Differential
Ball Bearing
External Brake
Internal Brake
Wheel
Wheel Drive End

Fig. 195.—Sectional View Showing White Bevel Gear Drive Rear Axle Used on Light Trucks.

Model T Ford Truck Axle.—The one-ton truck built by the Ford Motor Co. is practically the same in most details as the touring car, except that some of the parts are naturally made stronger and a new type of worm drive rear axle is used. This

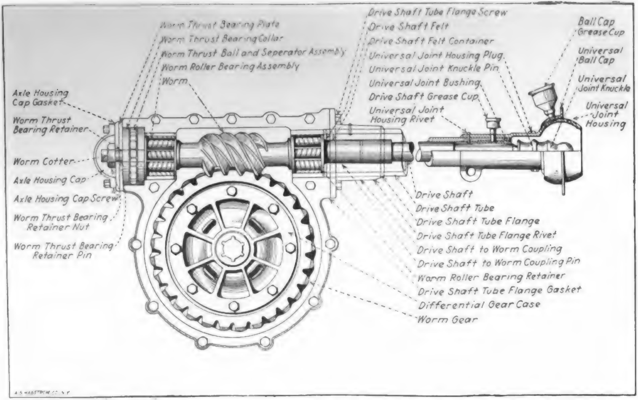

Worm Thrust Bearing Plate
Worm Thrust Bearing Collar
Worm Thrust Ball and Seperator Assembly
Worm Roller Bearing Assembly
Worm
Axle Housing Cap Gasket
Worm Thrust Bearing Retainer
Worm Cotter
Axle Housing Cap
Axle Housing Cap Screw
Worm Thrust Bearing Retainer Nut
Worm Thrust Bearing Retainer Pin
Drive Shaft Tube Flange Screw
Drive Shaft Felt
Drive Shaft Felt Container
Universal Joint Housing Plug
Universal Joint Knuckle Pin
Universal Joint Bushing
Drive Shaft Grease Cup
Universal Joint Housing Rivet
Ball Cap Grease Cup
Universal Ball Cap
Universal Joint Knuckle
Universal Joint Housing
Drive Shaft
Drive Shaft Tube
Drive Shaft Tube Flange
Drive Shaft Tube Flange Rivet
Drive Shaft to Worm Coupling
Drive Shaft to Worm Coupling Pin
Worm Roller Bearing Retainer
Drive Shaft Tube Flange Gasket
Differential Gear Case
Worm Gear

Fig. 195A.—Views of Worm Drive Gearing Used in Model T Ford Trucks, Rear Axle Showing Meshing of Worm and Worm Steel Driving Gearing.

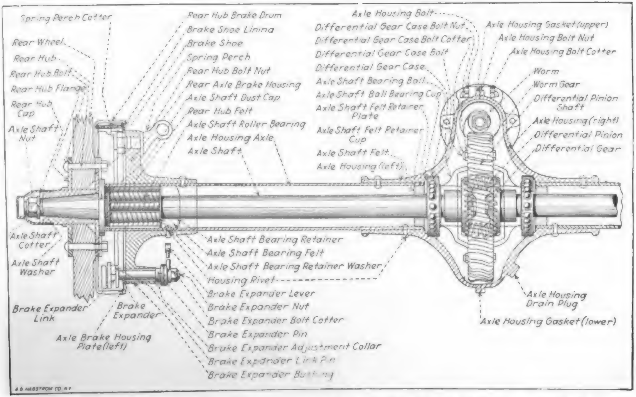

Spring Perch Cotter
Rear Wheel
Rear Hub
Rear Hub Bolt
Rear Hub Flange
Rear Hub Cap
Axle Shaft Nut
Axle Shaft Cotter
Axle Shaft Washer
Brake Expander Link
Axle Brake Housing Plate (left)
Brake Expander
Rear Hub Brake Drum
Brake Shoe Lining
Brake Shoe
Spring Perch
Rear Hub Bolt Nut
Rear Axle Brake Housing
Axle Shaft Dust Cap
Rear Hub Felt
Axle Shaft Roller Bearing
Axle Housing Axle
Axle Shaft
Axle Shaft Bearing Retainer
Axle Shaft Bearing Felt
Axle Shaft Bearing Retainer Washer
Housing Rivet
Brake Expander Lever
Brake Expander Nut
Brake Expander Bolt Cotter
Brake Expander Pin
Brake Expander Adjustment Collar
Brake Expdnder Link Pin
Brake Expander Bushing
Axle Housing Bolt
Differential Gear Case Bolt Nut
Differential Gear Case Bolt Cotter
Differential Gear Case Bolt
Differential Gear Case
Axle Shaft Bearing Ball
Axle Shaft Ball Bearing Cup
Axle Shaft Felt Retainer Plate
Axle Shaft Felt Retainer Cup
Axle Shaft Felt
Axle Housing (left)
Axle Housing Gasket (upper)
Axle Housing Bolt Nut
Axle Housing Bolt Cotter
Worm
Worm Gear
Differential Pinion Shaft
Axle Housing (right)
Differential Pinion
Differential Gear
Axle Housing Drain Plug
Axle Housing Gasket (lower)
A B HAGSTROM CO N Y

Fig. 195B.—The Axle Shafts and Supporting Bearings of the Ford Model T Truck Axle.

is clearly shown at Figs. 195A and 195B, the view at A showing the worm and its supporting bearings. That at B shows the worm gear and differential, also one of the axle shafts that drive the wheels. The axle is a live axle type, just as the bevel gear drive axle of the model T touring car is. The worm is at the top of the worm gear and differential assembly and the worm shaft is supported by roller bearings which take all radial load while end thrust is taken by a special ball bearing mounted at the back end of the worm shaft. The differential gear assembly is supported by cup and cone type ball bearings; the wheel end of the axle drive shaft revolves on a flexible roller bearing just as in the touring car. The power plant and control is the same as used in the passenger car, but the worm gearing provides a lower gear ratio on account of the greater weight to be moved. The spring at the rear end is much stronger and the frame is made of heavier section pressed steel.

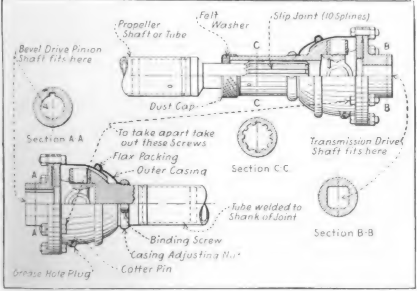

Felt Washer
Slip Joint (10 Splines)
Propeller Shaft or Tube
Bevel Drive Pinion Shaft fits here
C
B
C
B
Dust Cap
Section A-A
To take apart take out these Screws
Flax Packing
Outer Casing
Section C-C
Transmission Drive Shaft fits here
A
A
Tube welded to Shank of Joint
Section B-B
Binding Screw
Casing Adjusting Nut
Grease Hole Plug
Cotter Pin

Fig. 196.—Construction of Typical Universal Joint Outlined. When Two Joints are Used on a Shaft, One is Fixed Solidly to the Shaft, While the Other is Provided with a Splined Slip Joint.

Universal Joints.—The universal joint is an important element in practically all shaft drive trucks, some constructions using but one joint if the propeller shaft is protected by a long housing, as in the Ford, Dodge and Overland delivery models, while other systems employ two universal joints, one at each end of an exposed propeller shaft. Universal joints on many early cars were run exposed and considerable trouble was experienced due to rapid wear of the bearing parts. When exposed there was also considerable difficulty in keeping the joints properly lubricated. The modern forms are housed inside of a casing member, which is not only designed to exclude the dirt and grit from the bearing surfaces, but which is also depended on to retain lubricant.

Power from one unit to another is transmitted by shafting, called propeller shafting. Thus, the power of the engine is taken by the clutch and transmitted through a shaft to the transmission. From the transmission main shaft, another propeller shaft delivers power to the rear axle gearing. These propeller shafts are all fitted with two universal joints, but these vary in design. A popular type of joint is shown at Fig. 196, and is an all-metal construction. Universals are necessary in power transmission lines to prevent stresses due to misalignment. Thus, an axle moves up and down, due to inequalities in the road, altering its up-and-down relation to the transmission. If a propeller shaft were rigidly connected to both transmission and axle it would bend or break with movement of the axle. The universals allow the propeller shafts to move up and down or sideways, if necessary (universal movement, or movement in any direction). Flexible leather disc joints are shown at Fig. 197.

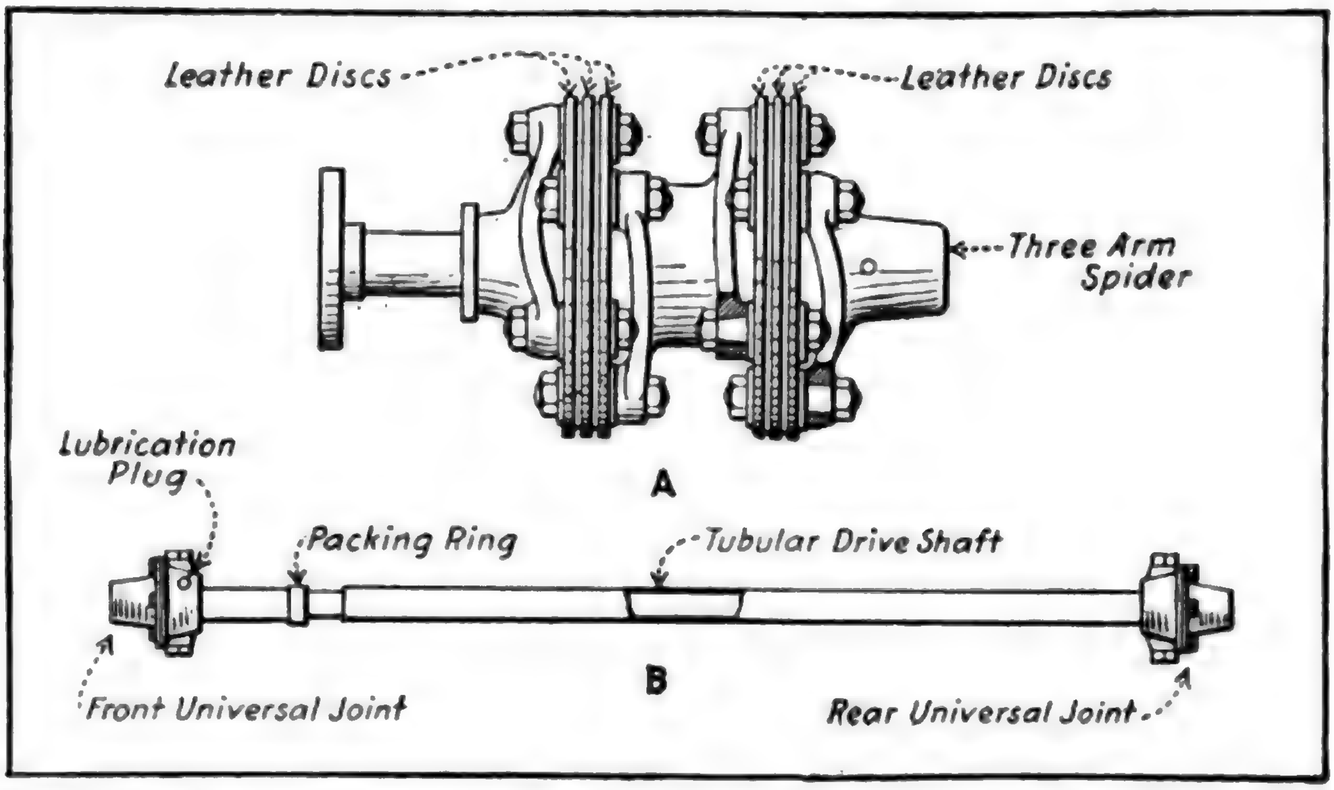


Fig. 197.—Recent Development in Power Transmission Members. A—Universal Joint Employing Leather Disk for Flexibility. B—Tubular Drive Shaft Reduces Liability of "Whipping."

The propeller shafts extending from the transmission to the axles are of various types. Some shafts are solid, with upset ends to receive driving splines or keys which are hardened on the surface. The universals are fitted to the ends of the propeller shafts, as shown at Fig. 198. A drive shaft with three universal joints, a design that is necessary with a long wheel base chassis, is shown at Fig. 199. The reader will note that an intermediate steadying bearing is required.

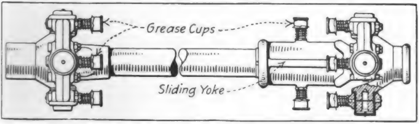


Fig. 198.—Diagram Showing Construction of Universal Joints Used on White Truck Chassis.

Attention is called to the sectional drawing at Fig. 202, showing the inclined position of the transmission resulting in a practically straight line drive, the maximum angularity of any of the propeller shaft joints not exceeding 2½°. Many universal joint manufacturers will tell you that their joints will work at an angularity of 10 per cent and over, but it has been found that when subjected to an angle of 6° or over, the best of them begin to give annoyance; while if working at 3° or 4° the wear is negligible. The practice of not exceeding 2½° is, therefore, very conservative and commendable, and will not only save

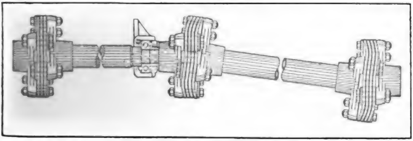


Fig. 199.—Diagram Outlining System to Power Transmission Through Two Shafts and Three Universal Joints When Chassis of Long Wheel Base are Employed. Note Ball Bearings Supporting Members at the End of Horizontal Drive Shaft. The Universal Joints Shown are of the Flexible Disc Type.

power but will reduce wear on the universal joint parts and prevent noise due to lost motion between yokes and pins.

Purpose of Differential Gear.—One of the most important elements of any form of motor truck driving system is the differential gear, but as this is usually placed at a point where it is not easily seen by the driver, and as but very little trouble is experienced from this mechanism, many operators of trucks are not aware of its existence and do not realize the important work performed by this relatively simple component. Without a differential gear it would be difficult to control the machine when driving around corners, so this really performs an important function with both steering and driving systems.

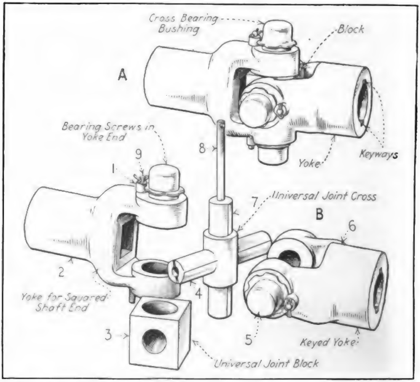

Cross Bearing Bushing
Block
A
Keyways
Yoke
Bearing Screws in Yoke End
9
1
8
7
Universal Joint Cross
B
6
2
Yoke for Squared Shaft End
4
3
5
Keyed Yoke
Universal Joint Block

Fig. 200.—Typical Universal Joint Shown at A and the Parts of Which It is Composed Outlined at B.

When turning corners with a four-wheeled vehicle the outer wheels must turn at a higher rate of speed than the inner ones, because they are describing a larger arc of the circle. The more sharply the vehicle is turned, the greater the difference in velocity between the inner and outer wheels. In a horse-drawn conveyance all the wheels are independent of each other and may all revolve at different speeds, if necessary, without interfering with each other or impairing the action of the conveyance. In a truck different conditions prevail, because while the front wheels are usually independent of each other, the driving wheels must be connected together so that each will receive its share of the energy produced by the motor and will perform its quota of work incidental to propelling the vehicle.

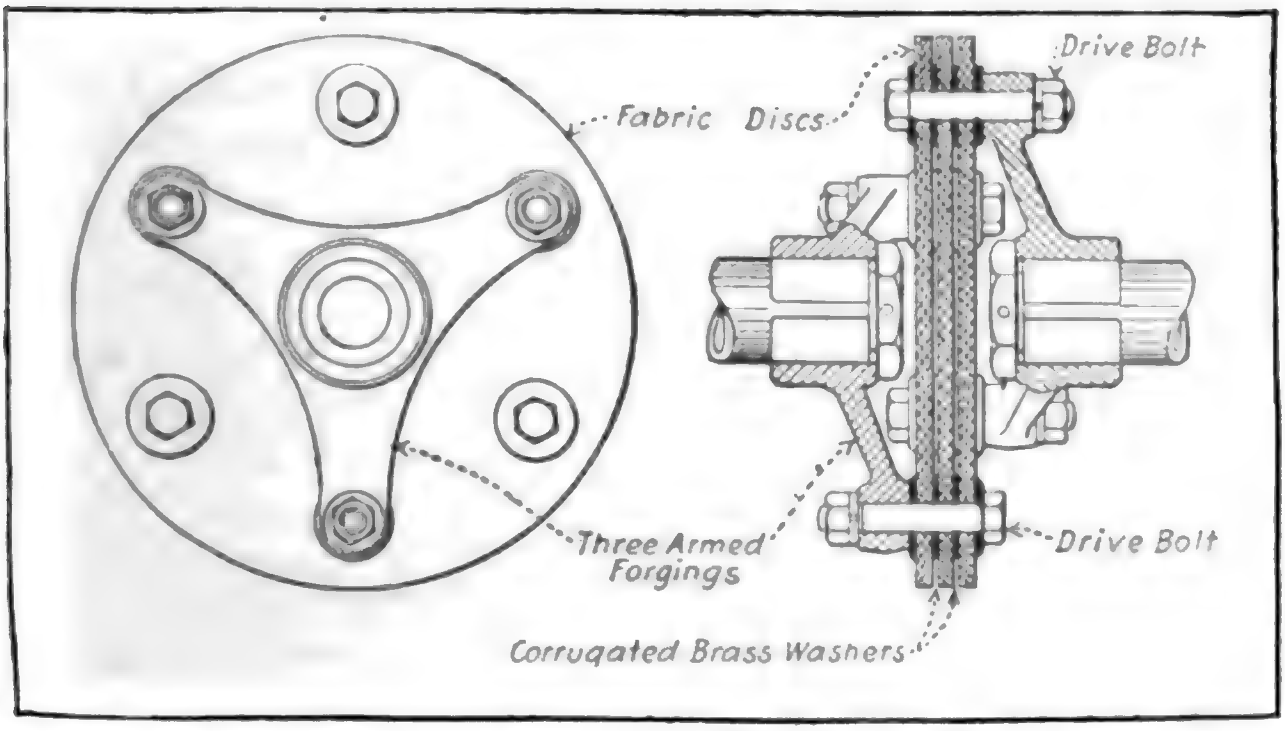


Fig. 201.—Drawing Showing Construction of Simple Fabric Disc Type Universal Joint.

In order to permit one of the driving wheels (the inner one) to turn at a lower speed than its mate in rounding a corner, the balance or differential gear is used. Its simplest application is shown at Fig. 203. From this it is patent that the driving axle is split in the center and that the wheels are mounted on and driven by distinct shafts. At the inner end of each shaft a bevel gear is carried, these being firmly secured to the axles so they revolve with them. The main bevel-driven gear, which is actuated by the driving pinion turned by the engine shaft, is mounted independently of the axles and is coupled to them by means of small bevel pinions which are applied so that they will drive the gears on the axle shafts. Assuming that all the gears are in mesh, as outlined, and the power is being applied to the driven gear, and that the resistance to traction is the same at both rear wheels, the entire assembly, comprised of driven gear, the differential pinions attached to it and the axle shafts, revolve as a unit.

If the resistance against the driving wheels varies so one wheel tends to revolve faster than the other, the differential pinions will not only turn around on the studs on which they are mounted, but at the same time will run around the gears on the axle shafts, because the bevel-driven gear is carrying the studs on which the differential pinions revolve forward. When turning a corner the outer wheel must turn so much faster than the inner member that it is just the same as though one of the wheels was held stationary and the other turned. If both wheels are turning forward at the same speed, the differential pinions remain stationary and act simply as a lock which forms a driving connection between gear No. 1 on axle shaft No. 1 and gear No. 2 on axle shaft No. 2. This will mean that both wheels must turn in the same direction as long as the work is uniformly distributed. Just as soon as the resistances are unequal the differential pinions will turn on their supporting stud, and one member may turn at comparatively slow speed while the other revolves at a much faster rate.

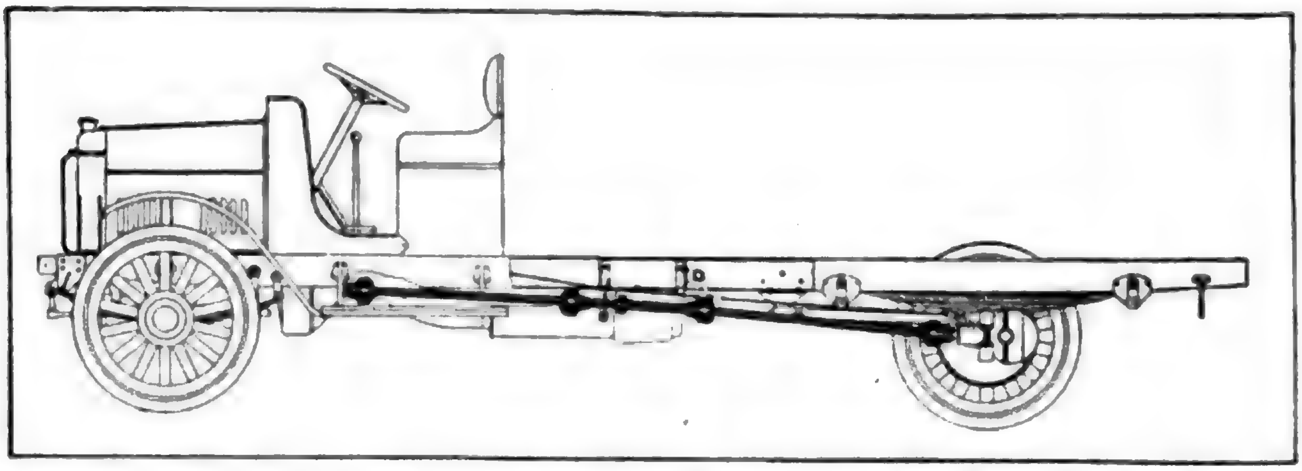


Fig. 202.—Diagram of Truck Chassis Showing How Practical Straight Line Drive May Be Obtained by Placing the Engine in the Frame So that the Crankshaft is at an Angle with the Side Frame Member.

The action of the differential pinions may be clearly understood by reference to Fig. 203, and giving due consideration to the following principles: The same resistance at the point of contact between the driving wheels and the ground prevents the pinions from revolving on their own studs, and in this case they are carried around by the supporting members and the ring gear. If the resistance upon axle shaft No. 1 is greater than that on axle shaft No. 2, the ring gear will rotate forward with the wheel offering the least resistance, and the differential pinions will turn on their studs and run over the surface of the gear which tends to remain stationary, this being the one against which there is the greatest resistance. The differential pinions can thus turn independently of one gear wheel and run over its surface without turning it, and at the same time act as a clutching member of sufficient capacity on the other gear and axle to carry them in the same direction as the ring gear and at the ratio of speed which will depend upon the difference in resistance between the driving members and the ground.

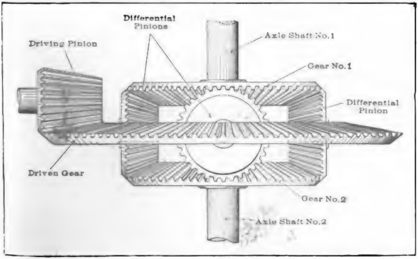


Fig. 203.—Illustrating Differential Gear Action When Applied to Bevel Gear Drive Axle.

The differential gear described is of the bevel pinion type, and its application to the driving gear carrier of the I. H. C. truck axle is shown at Fig. 204. Other forms have been devised in which the differential action is obtained by means of spur gearing, which utilizes the same principle of compensation. Various friction and leverage combinations have been adapted in an endeavor to secure a differential action, but these have eventually been displaced by the simpler and more efficient geared forms. The differential gear which utilizes bevel pinions is the form that is more generally used, and has proved to be the simplest, most efficient and enduring. The differential gear is usually incorporated in the rear axle if the drive is by shaft and in the countershaft if transmission is by means of side chains.

The conventional differential, rather than being inefficient, is, on the other hand, too efficient in that it differentiates for all differences, whereas the truck engineer wants it to take care only of the unequal velocities of the rear wheels. It becomes inefficient as a means of transmitting the power to the rear wheels if the wheels have unequal traction. It is to correct this defect of differentiating for unequal traction of the wheels that a great many intended substitutes for the present types of differential have been invented.

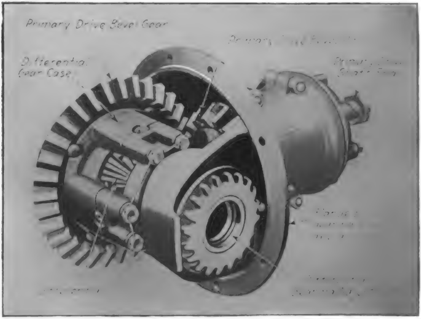


Fig. 204.—Differential and Bevel Drive Gear Assembly of the International Harvester Truck Axle.

New Positive Drive Differential.—A new type of worm differential, which is of exceedingly simple design, and which has the meritorious feature of driving both wheels, regardless of the traction conditions of either, has been put on the market under the name of the Walter positive drive differential. The differential consists of two pairs of spiral gears mounted in a two-part housing, as shown in the accompanying illustration, Fig. 205. The two pairs of spiral gears mesh together and also mesh with worms mounted in the housing and on the drive-shaft. The housing is in halves which are alike except for the flange for the

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bevel gear. The two bolts which hold the housing together set one ahead of the other in order to bring the spiral gear pairs into direct mesh.

The worm can be given any desired pitch within the limits of good practice, but in the standard design they will have a 22.5

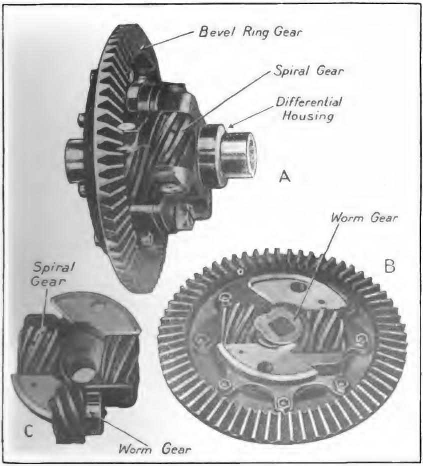

Fig. 205.—**Assembly View of Walter Positive Drive Differential at A. View of Ring Gear, Differential Parts and Worm Gearing at B.**

degree lead angle, as this has been found to be the best in practice. The construction is not limited, however, to any special spiral angle. With this construction, the operation will be as follows: The driving resistances of the wheels tend to rotate the spiral gears on their pins in opposite directions. When one wheel has a greater resistance the inequality of force cannot drive the other wheel faster, as the spiral gear cannot drive the worm on account of the relationship of the pitch angle to one another. The result is that both wheels are positively driven. When turning, the outside wheel rolls faster and so permits the inside wheel to turn correspondingly slower, giving a compensating differential action.

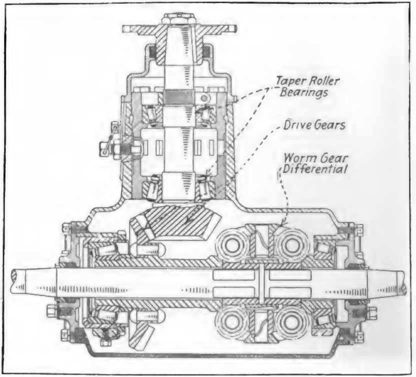

Fig. 206.—One of the Driving Units of the Nash Quad Truck Showing Location of Worm Differential Gearing and Method of Supporting Parts by Taper Roller Bearings.

Worm gearing has been chosen because it provides strength, while at the same time giving a smooth and pliant action. The flexibility of the worm gearing is very effective in diminishing the shocks transmitted through the differential mechanism. Five advantages are claimed for this type of differential. These may be briefly summarized as follows: 1—The car will not stall if a single wheel alone has traction. 2—The motor power is used more effectively, as both wheels are steadily driven. 3—Skidding is eliminated in many cases, due to the steady driving of both wheels. 4—More even pulling is secured on a rough road for the same reason. 5—The wear and strain on tires due to an accelerated or spinning wheel recovering the road is eliminated, a notable advantage for economy.

As will be noted from the foregoing description, this differential is different in construction and principle from the 45-degree type and the ratchet differentials, which have an overrunning action. The widest difference between the 45-degree and this is that it is a positive drive, in the first place, and, secondly, it is irreversible, whereas it is the nature of the 45-degree gears to be perfectly reversible. The distinction between the Walter differential and the ratchet differential is twofold as far as operation is concerned. In the first place, it has not an overrunning action, and, secondly, instead of driving the wheel of most resistance, the two wheels are given equal power.

Experiments have been made with solid axles, eliminating the differential. These are only suitable for slow-speed trucks using solid tires and operating on good roads. The experiments made do not show any advantages in either trucks capable of moderate speeds or pleasure cars capable of running at high speeds. There is considerably more wear on tires, and trucks are harder to steer than when a differential gear is employed.

The sectional view at Fig. 206 shows one of the worm gear differential assemblies used on the Nash four-wheel drive truck and outlines a well-proven type of gear of this character. The construction is apparent by study of the illustration.

Worm Drive Gearing.—Worm gearing is not only enduring and noiseless, but is remarkably efficient, as actual tests have demonstrated that from 90 to even as high as 95 per cent of the horsepower applied to the worm driving shaft has been delivered to the road wheels. The sectional view at Fig. 207 and other illustrations clearly show the method of supporting the worm shaft by anti-friction bearings and the way the worm gearing is applied. In all cases the worm is made of hardened steel and is either triple or quadruple-threaded, having a lead angle sufficiently acute to provide the factor of reversibility, which is essential in truck service. To one familiar with mechanics it will be apparent that, while it is possible to exert great power and secure a great ratio of speed reduction with a gradual pitch worm, the construction would be almost irreversible. This factor of irreversibility, while very desirable in such

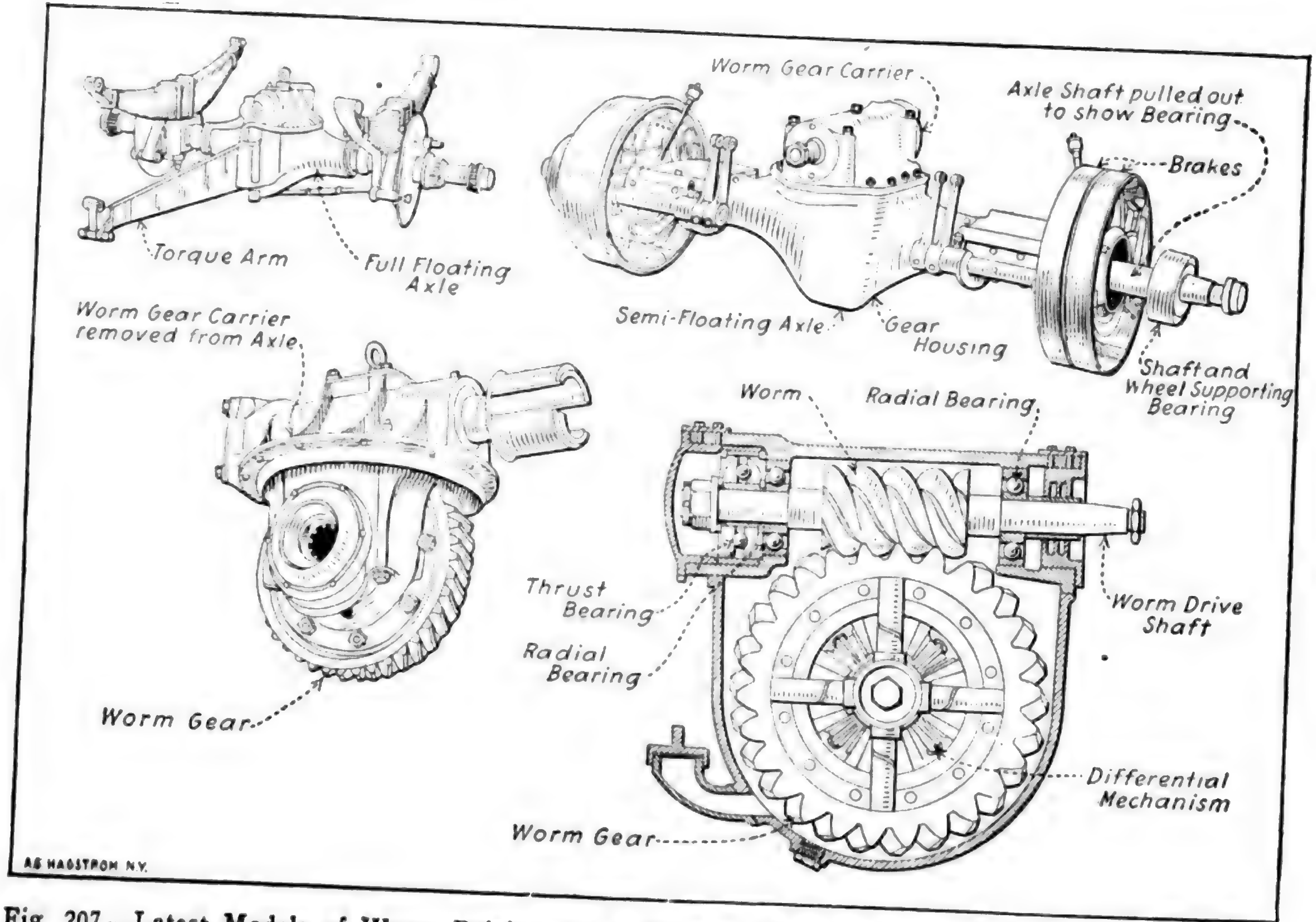
Torque Arm
Full Floating Axle
Worm Gear Carrier
Axle Shaft pulled out to show Bearing
Brakes
Semi-Floating Axle
Gear Housing
Shaft and Wheel Supporting Bearing
Worm Gear Carrier removed from Axle
Worm
Radial Bearing
Thrust Bearing
Radial Bearing
Worm Drive Shaft
Worm Gear
Differential Mechanism
Worm Gear
AG HAGSTROM N.Y.

Fig. 207.—Latest Models of Worm Driving Axles Showing Method of Mounting Worm Gearing in a Removable Carrying Member.

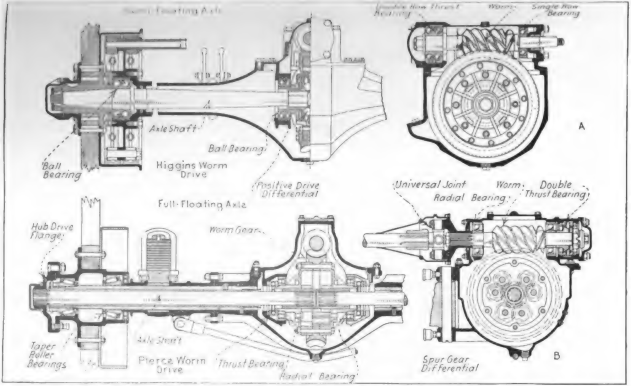
Semi-Floating Axle
Double Row Thrust Bearing
Worm
Single Row Bearing
A
Axle Shaft
Ball Bearing
Ball Bearing
Higgins Worm Drive
Positive Drive Differential
Full-Floating Axle
Universal Joint
Radial Bearing
Worm
Double Thrust Bearing
Hub Drive Flange
Worm Gear
Taper Roller Bearings
Axle Shaft
Pierce Worm Drive
Thrust Bearing
Radial Bearing
Spur Gear Differential
B

Fig. 208.—The Higgins Worm Drive Truck Axle. At A Uses a Positive Drive Differential in Which Steel Balls Working in Cam Grooves are Employed. The Axle is a Semi-Floating Type, the Wheel Load Being Carried by a Drive Shaft. The Worm Drive Axle of the Pierce-Arrow Truck is of the Full Floating Type and Wheel Loads are Carried by the Axle Housing Member. The Differential is a Spur Gear Type.

mechanism as truck steering gears, would not be practical under those conditions where the worm wheel must become the driver as in coasting.

The worm gear assembly, which is ordinarily combined with the differential gearing, is nearly always attached to a carrier member which fits into the main axle housing. Such an assembly is shown just above the sectional view of the worm gear at Fig. 207 and in place in the axles at Fig. 208. A phantom view of the worm gearing used in Packard trucks is shown at Fig. 209. The reason for this construction is that it is essential that the worm gearing be accurately adjusted and that this adjustment be maintained. It is not only important that the worm should mesh properly, but the center line of the worm must coincide exactly with the center line of the worm gear or considerable friction and actual depreciation will ensue. It was fortunate, indeed, that in the truck applications the gear ratios desired, ranging from a reduction of eight to one in the lighter trucks to fifteen or sixteen to one in the heavier vehicles, were not so low as to demand gradual pitch single-threaded and practically non-reversible worms. As the worm gearing is invariably

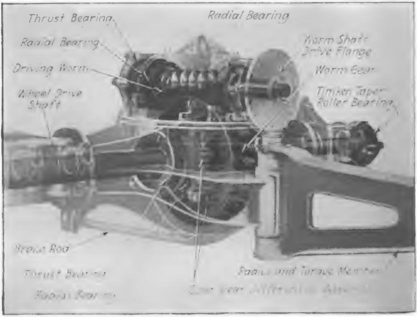
Thrust Bearing
Radial Bearing
Radial Bearing
Worm Shaft Drive Flange
Driving Worm
Worm Gear
Wheel Drive Shaft
Timken Taper Roller Bearing
Brake Rod
Thrust Bearing
Radius and Torque Member
Spur Gear Differential Assembly
Radial Bearing

Fig. 209.—Phantom View Showing Construction of the Packard Worm Drive Axle and Showing Driving Gearing and Spur Gear Differential.

carried in a casing that may be filled with lubricating oil, and as there is no opportunity for grit or dirt to enter, it will be apparent that long life is assured.

Double Reduction Axles.—Another form of final drive system that is receiving considerable attention at the present time is a double reduction axle of the type in which a primary reduction in speed is obtained between bevel gears, while a secondary and final reduction in speed is secured by driving the wheels through the medium of internal gearing. It is conceded that internal spur gearing is the most efficient form, and when it is applied

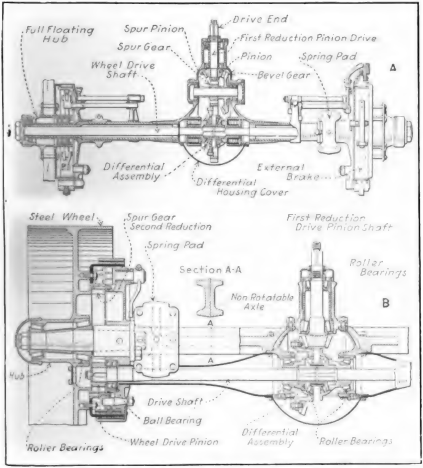
Drive End
Full Floating Hub
Spur Pinion
Spur Gear
First Reduction Pinion Drive
Pinion
Spring Pad
Wheel Drive Shaft
Bevel Gear
A
Differential Assembly
External Brake
Differential Housing Cover
Steel Wheel
Spur Gear Second Reduction
First Reduction Drive Pinion Shaft
Spring Pad
Roller Bearings
Section A-A
Non Rotatable Axle
B
A
A
Hub
Drive Shaft
Ball Bearing
Differential Assembly
Roller Bearings
Wheel Drive Pinion
Roller Bearings

Fig. 210.—Two Forms of Double Reduction Live Axles. A—Combination Bevel and Spur Gear Drive Forms. B—Internal Gear Drive Truck Axle.

properly to rear axle construction one obtains advantages that are worthy of consideration. An internal gear-driven axle, as can be readily ascertained from inspection of the part sectional view, Fig. 210, B, is a form in which the jackshaft, which is ordinarily placed on the chassis frame in the chain and sprocket drive system, is attached to the axle—in this instance, a non-rotating member on which the wheels revolve freely. Instead of sprockets at the end of the live axle shafts, small spur pinions are mounted which mesh directly with the large internal gears bolted to the brake drums, which in turn are securely fastened to the wheel hubs. Other internal gear-drive axles are shown at Fig. 212 and Fig. 215. The worm axle is a built-up form and must be made very strong, because the housing for the driving gearing and axle shafts must be heavy enough to carry the load as well as enclosing the transmission members. On large capacity

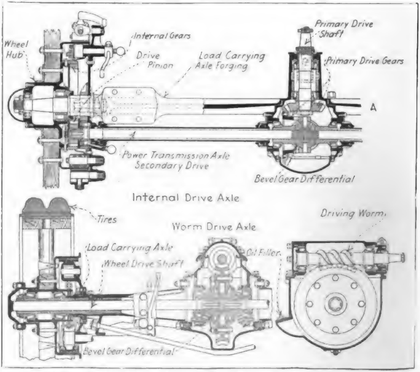
Wheel Hub
Internal Gears
Drive Pinion
Load Carrying Axle Forging
Primary Drive Shaft
Primary Drive Gears
A
Power Transmission Axle Secondary Drive
Bevel Gear Differential
Internal Drive Axle
Tires
Worm Drive Axle
Driving Worm
Load Carrying Axle
Wheel Drive Shaft
Oil Filler
Bevel Gear Differential

Fig. 211.—Sectional Views Comparing Construction of Internal Drive Axle at A and Typical Light Worm Drive Axle at B. In Both of These Designs the Axle Shafts are Used Only to Transmit Power and Do Not Carry Any of the Truck Weight.

trucks a live axle construction becomes of necessity very massive and correspondingly heavy. The two forms of axles may be compared by reference to Fig. 211. The double reduction form of axle shown at Fig. 210, A, is popular abroad, much more so than in this country. This follows the usual full floating axle construction as regards the wheel mounting and has the differential assembly driven by spur gearing instead of bevel gears. The first reduction is secured by a bevel pinion which meshes with a bevel gear carried on a short countershaft. A spur pinion on the countershaft drives the spur gear on the differential.

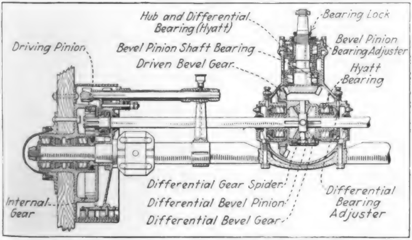
Hub and Differential Bearing (Hyatt)
Bearing Lock
Driving Pinion
Bevel Pinion Shaft Bearing
Bevel Pinion Bearing Adjuster
Driven Bevel Gear
Hyatt Bearing
Differential Gear Spider
Differential Bevel Pinion
Differential Bevel Gear
Internal Gear
Differential Bearing Adjuster

Fig. 212.—Sectional View of the Internal Gear Axle Used on International Harvester Trucks.

Truck. Axle With Planetary Secondary Reduction.—A truck axle embodying a new form of final drive has been developed by the Flint Motor Axle Co. It is the intention to manufacture this axle for trucks in capacities from one ton up, and the 1½-ton capacity truck axle will be put in production first.

As may be seen by reference to the sectional illustration, Fig. 215A, reproduced from "Automotive Industries," there is a first reduction of the transmission speed by bevel gears at the center of the axle and a final reduction by a set of planetary gears at the ends of the axle. Therefore, the torque transmitted by the differential and axle shafts is comparatively small and it is not necessary to build the axle as heavily as would otherwise be necessary. The reduction at the bevel gears is only 2.14 to 1, hence the torque on each axle shaft is only slightly more than that on the propeller shaft. Bevel gear drive and differential are of conventional construction.

To the end of the axle shaft is secured, by means of a splined fitting, a spur pinion meshing with three equally spaced planetary pinions carried on studs secured into a housing that is bolted to the outside of the driving wheel hub. These planetary pinions also mesh with an internal gear ring, which is keyed to the end of the axle tube. One advantage of this form of transmission is that it gives a high road clearance at the center of the axle, while at the same time it permits of enclosing all members of the transmission and operating them in oil.

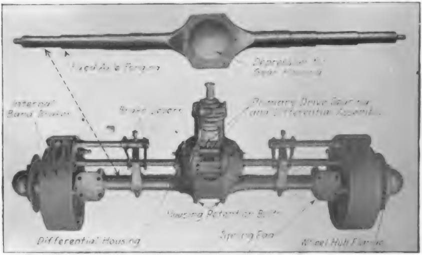
Fixed Axle Forging
Depression for Gear Housing
Internal Band Brakes
Brake Levers
Primary Drive Gearing and Differential Assembly
Housing Retention Bolts
Differential Housing
Spring Pad
Wheel Hub Flange

Fig. 213.—View at A Shows the Forged Steel Dead Axle Member Used on International Harvester Trucks. The View at B of the Complete Axle Shows How the Differential and Drive Gear Housing is Bolted to the Forge Load Carrying Member Shown at A. This Illustration Also Outlines the Double Internal Brakes.

The axle illustrated at Fig. 215A has a tread of 56 inches and a carrying capacity of 3,800 pounds on the spring seats. The latter are normally spaced, with 39-inch centers for 2½-inch width, ⅝-inch clips, but spring centers can be varied from 38 to 40 inches. Total gear reductions of from 7⅛ to 8.8 can be obtained, the bevel gear ratio being varied from 2.14 to 2.647, whereas the planetary gear ratio remains constant at 3.33. The bevel gears are of five diametral pitch with 1¼-inch face and the planetary gears of 6-8 diametral pitch by ¾-inch face.

The brake drums are 14 inches in diameter by 2½ inches face, and external and internal brakes act on the same drums. Hyatt roller bearings are fitted in the wheel hubs and directly back of the pinion on the pinion shaft, while New Departure ball bearings are fitted at the outer end of the pinion shaft and on the differential. The axle shafts are made from chrome nickel steel splined at both ends and heat treated.

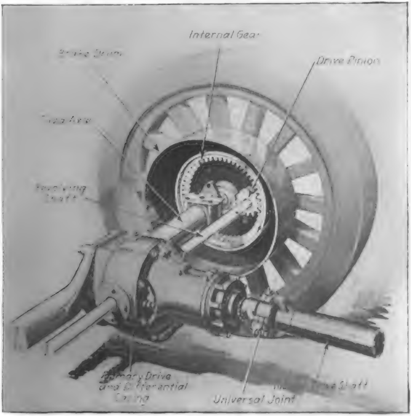
Internal Gear
Brake Drum
Drive Pinion
Revolving Shaft
Primary Drive and Differential Casing
Universal Joint
Drive Shaft

Fig. 214.—Diagram Showing Method of Power Transmission by Means of Pinion and Internal Gear at the Wheel End of the Axle of International Harvester Trucks.

Four-Wheel Drive and Steer System.—Gasoline trucks have been designed where the drive is through all four wheels which combine directive and tractive functions. A side elevation of the new Nash four-wheel drive motor truck with important parts depicted is clearly shown at Fig. 216, and a simplified sectional view at Fig. 217. In this, the power is obtained from a Buda power plant driving through a dry disc clutch to a change-speed gear of special construction mounted on the chassis frame about

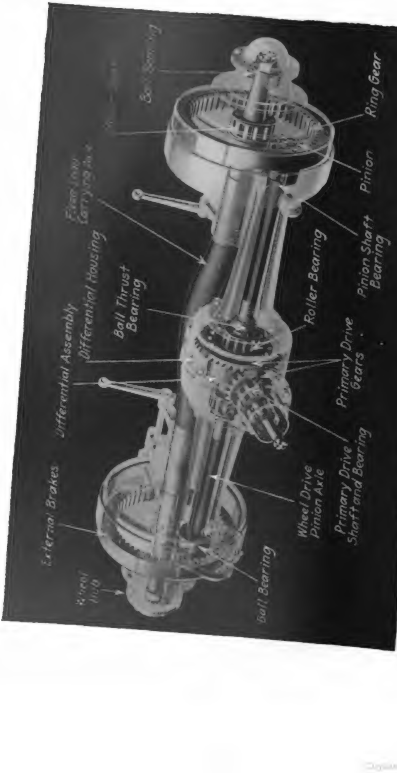
Wheel Hub
External Brakes
Differential Assembly
Differential Housing
Ball Thrust Bearing
Fixed Load Carrying Axle
Ball Bearing
Ring Gear
Pinion
Pinion Shaft Bearing
Roller Bearing
Primary Drive Gears
Primary Drive Shaft and Bearing
Wheel Drive Pinion Axle
Ball Bearing

Fig. 215.—Phantom View of the Clark Internal Gear Axle Clearly Showing All Important Parts.

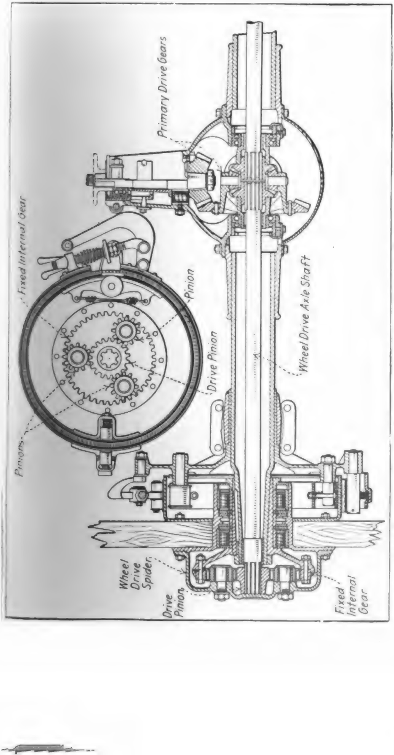
Pinions
Fixed Internal Gear
Pinion
Drive Pinion
Wheel Drive Axle Shaft
Primary Drive Gears
Wheel Drive Spider
Drive Pinion
Fixed Internal Gear

Fig. 215A.—Internal Gear Drive Axle with Planetary Reduction Gearing at Wheel End.

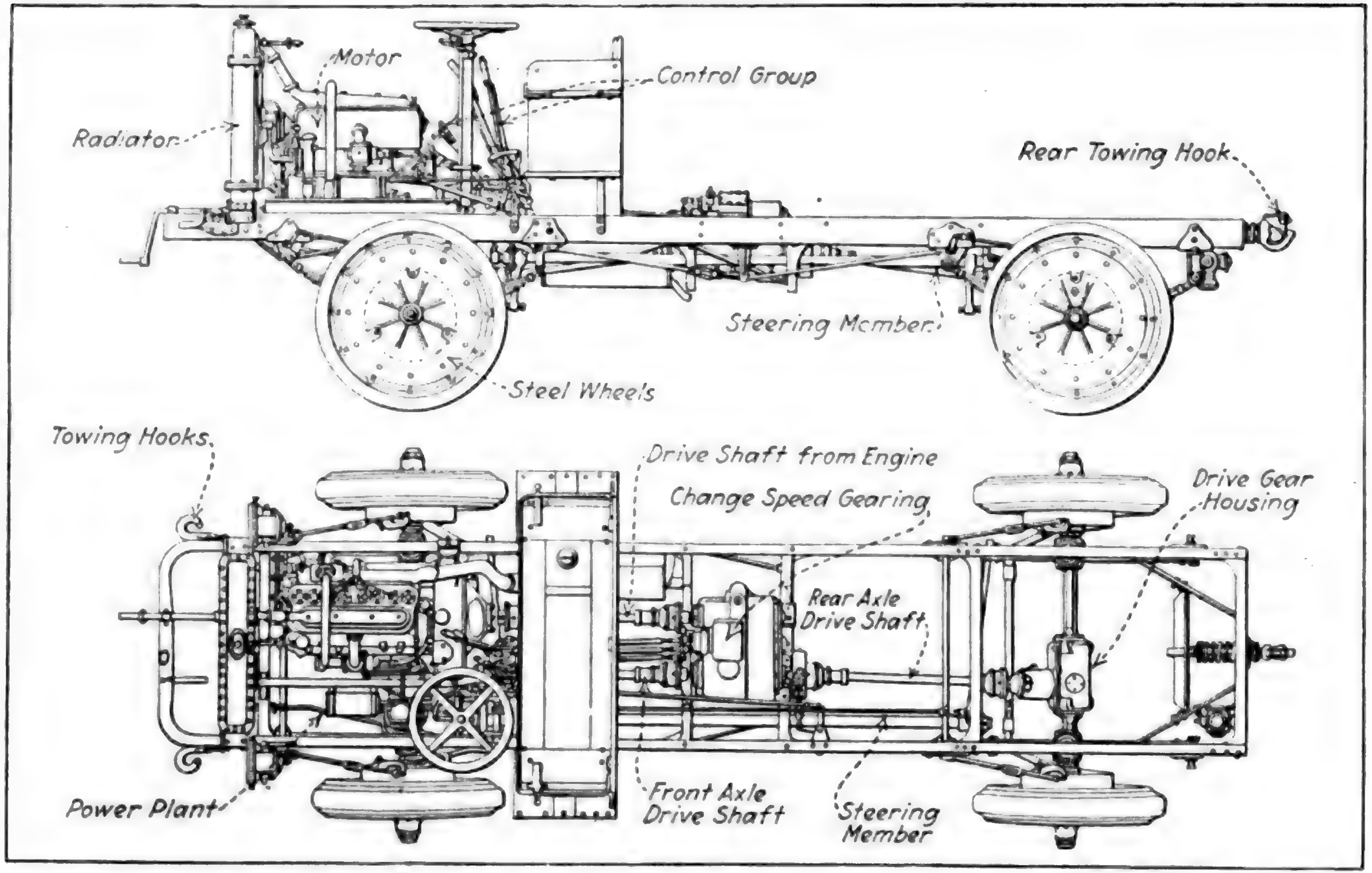
Motor
Control Group
Radiator
Rear Towing Hook
Steering Member
Steel Wheels
Towing Hooks
Drive Shaft from Engine
Change Speed Gearing
Drive Gear Housing
Rear Axle Drive Shaft
Power Plant
Front Axle Drive Shaft
Steering Member

Fig. 216.—Views of the Two-Ton Nash Quad Truck Showing Construction of Parts and Method of Driving Both Axles from One Gearbox Located at the Center of the Frame.

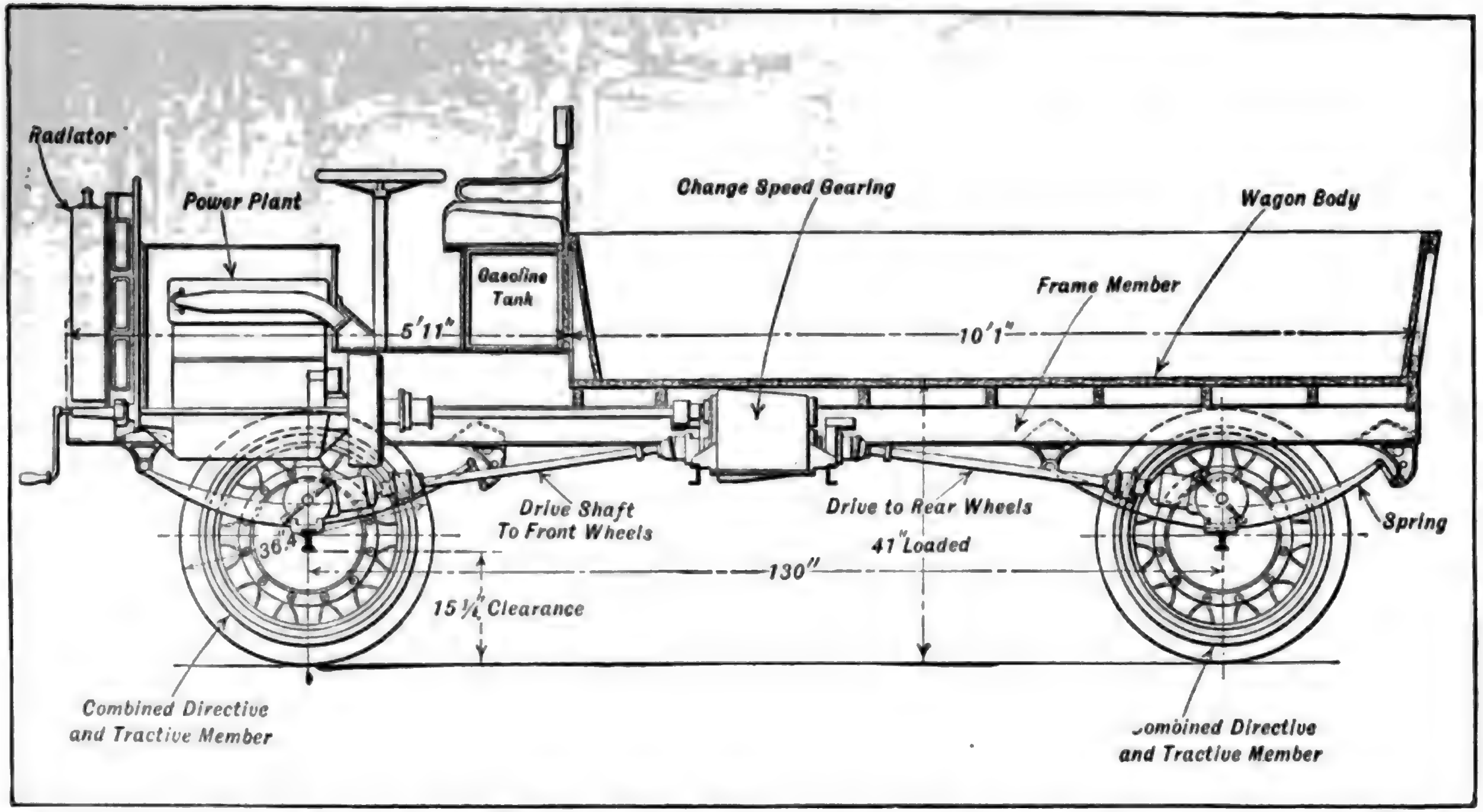
Radiator
Power Plant
Gasoline Tank
5'11"
Change Speed Gearing
Wagon Body
Frame Member
10'1"
Drive Shaft To Front Wheels
Drive to Rear Wheels
41" Loaded
Spring
36.4
130"
15¼" Clearance
Combined Directive and Tractive Member
Combined Directive and Tractive Member

Fig. 217.—Simplified Side Elevation of Four-Wheel Drive Truck Showing Method of Drive from the Engine and Change Speed Gearing and from That Member to the Front and Rear Axles.

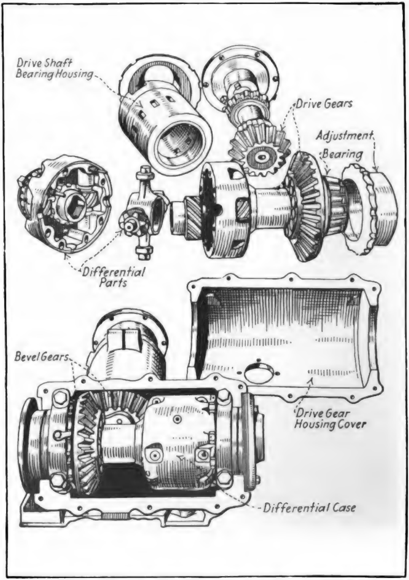
Drive Shaft Bearing Housing
Drive Gears
Adjustment
Bearing
Differential Parts
Bevel Gears
Drive Gear Housing Cover
Differential Case

Fig. 218.—View Detailing Important Parts of the Differential and Drive Gear Assembly of the Nash Quad Axle.

midway between the front and rear axles. One drive shaft extends from the front end to the front axle, while a similar member transmits power to the rear axle, which is a duplicate of that used at the front of the car.

A special form of gear box is necessary. In this the drive is

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through gearing at all speeds, there being no direct drive clutch, as is true of conventional gearsets. The transmission provides four speeds forward and a reverse and, in addition to the usual countershaft carried below the main shaft, a quill is mounted below this which carries a differential gear. From this differential two drive shafts provided with universal joints transmit the power to two auxiliary differentials located on the front and rear axles respectively, and clearly shown at Fig. 218. The

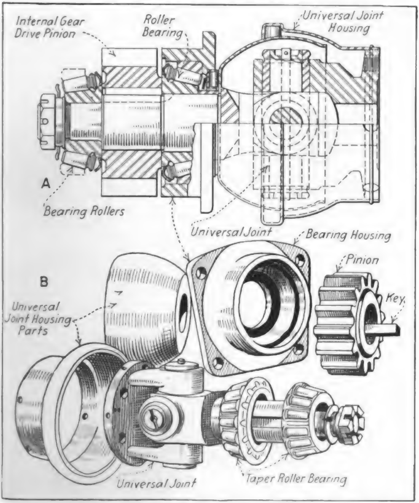

Internal Gear Drive Pinion
Roller Bearing
Universal Joint Housing
A
Bearing Rollers
Universal Joint
Bearing Housing
Pinion
B
Key
Universal Joint Housing Parts
Universal Joint
Taper Roller Bearing

Fig. 219.—Universal Joint and Wheel Drive Pinion Used on Nash Quad Axle. Sectional View at A Shows Assembling of Different Parts While View at B Outlines the Appearance of the Parts When Dismantled.

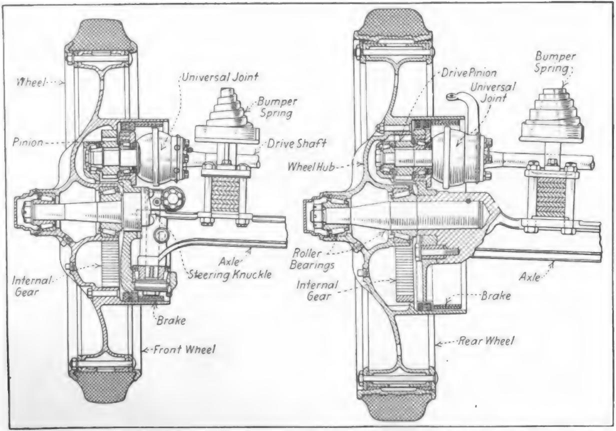

Wheel
Universal Joint
Bumper Spring
Pinion
Drive Shaft
Internal Gear
Axle
Steering Knuckle
Brake
Front Wheel
Drive Pinion
Universal Joint
Bumper Spring
Wheel Hub
Roller Bearings
Internal Gear
Axle
Brake
Rear Wheel

Fig. 220.—Sectional View Showing Construction of Nash Quad Truck Wheels. The Form Outlined at A is used When Wheels Combine Directive and Tractive Functions. The Form Detailed at B

differentials on the axles in turn drive the wheels, and as the wheels are movable to steer the vehicle, as well as rotatable to drive it, it is apparent that the final drive shafts which transmit power to the wheels must have universal joints to compensate for wheel movement when set at an angle to direct the vehicle.

One of the universal joints employed at the wheels is shown at Fig. 219. The universal joint is a regular double yoke and cross type enclosed in a housing that protects it from the dirt and grit and which permits of considerable movement of the drive shaft without allowing the lubricant with which the universal joint is packed to escape. One end of the universal joint is attached to the drive shaft which runs to the differential on the axle, while the other yoke drives a spur pinion which is well supported by a taper roller bearing placed at each side. This spur drive pinion engages with an internal spur gear carried within the body of the wheel, and applies the power near the wheel rim, thereby gaining the greatest driving leverage possible. The internal gear of the wheel and the pinion driving it are well housed to exclude grit and retain lubricant, and this housing at the same time serves as a brake drum.

The wheels, one of which is shown at Fig. 220, A, are interchangeable in the four-wheel steer forms, but in the models in which only the front wheels steer, the rear wheels are as shown at Fig. 220, B. They do not differ materially in construction, however, and axles are practically the same except for the elimination of the steering knuckles in the form shown at B. The two drive axles with their universals are duplicates of each other, and the three differential gears, consisting of that in the gearbox and those on the axles, are all alike. The differential is a special Wayne type, which differs from the common construction in that it automatically drives the wheel which has the greatest resistance and which has traction, and this feature, coupled with the use of four driving wheels, makes it possible to propel the truck if any one of the four wheels has traction. It is claimed that while the truck has 120-inch wheel base, it will turn in a circle of twenty-two feet radius, which is accomplished by the four-wheel steering feature. There are four ample brakes, one on each wheel, and it is claimed that either set of two brakes is sufficient to hold the loaded truck on a thirty per cent grade. The wheel revolves on taper roller bearings carried by the wheel spindle. The steering knuckle is a

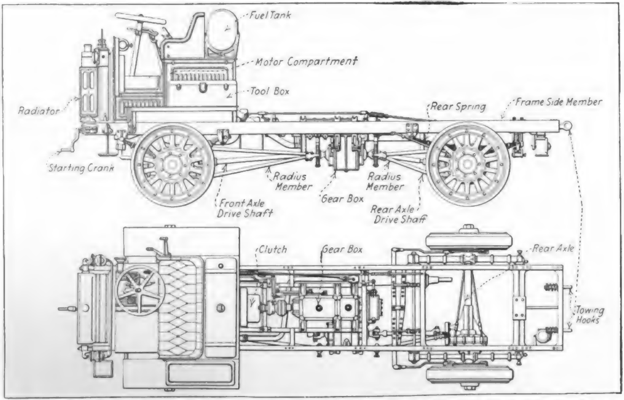

Fuel Tank
Motor Compartment
Tool Box
Radiator
Rear Spring
Frame Side Member
Starting Crank
Radius Member
Gear Box
Radius Member
Front Axle Drive Shaft
Rear Axle Drive Shaft
Clutch
Gear Box
Rear Axle
Towing Hooks

Fig. 221.—Side Elevation and Plan View of the Four-Wheel Drive Model B Three-Ton Truck Chassis Showing Arrangement of Change Speed Gearing and Driving Mechanism.

special form of the inverted Elliot type, and not only carries the wheel spindle, but the frame supporting the spur driving pinion as well. The loaded front axle is supported by a taper roller bearing at the lower end of the steering knuckle which makes it possible to turn the wheel with minimum exertion on the part of the operator. When the wheel is moved by the steering knuckle the frame carrying the spur drive pinion turns as well, but owing to the universal joint the drive is not interrupted and the wheels are all driven regardless of whether they are in a straight-ahead position or at an angle to steer the car. Other vehicles have been evolved and applied as tractors for fire department service where the drive is through the front wheels only, these members being very similar in construction to the form described.

Four-Wheel Drive Truck Details.—In the four-wheel drive chassis construction, shown at Fig. 221, the transmission system calls for front and rear axles of different design. The front axle, which is shown at Fig. 222, is of the type where the wheels must have combined directive and tractive functions—i.e., it must be possible to displace these angularly with relation to the axle for steering purposes and at the same time transmit power to them while they are so displaced. This is accomplished by interposing universal joints in the driving system, having these members installed in housings so that the center line of the universal joint coincides approximately with that of the steering knuckle. A drive shaft extends from the differential gear to the steering knuckle, and a short shaft transmits the power from that point through the hollow wheel supporting member to the hub drive clutch. The rear axle, which is shown at Fig. 223, is a considerably simpler construction, because it is used only for transmitting power to the wheels and follows conventional live axle construction. It is a full floating type in which the wheels are supported by bearings on the axle housing and the drive shafts extending from the bevel gear-driven differential are called upon only to transmit power and not to carry any of the weight of the truck or its load.

Mr. H. A. Lewis, of Billings, Montana, with an F. W. D. stock chassis, rode up a 66⅔ per cent grade to demonstrate the tractive power of this type of truck as shown at Fig. 224, coming to a full stop at four different stages, and started again from these positions without requiring one inch of start. The motor did

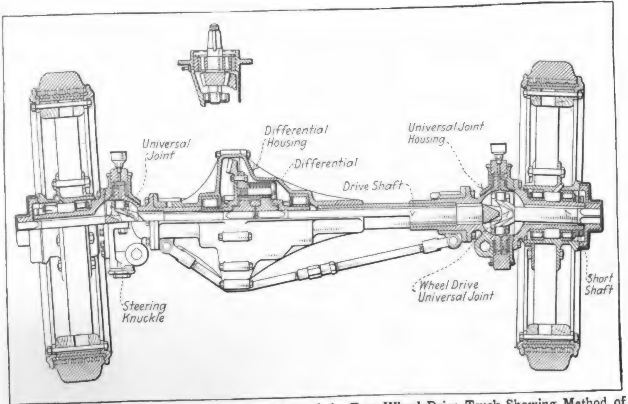

Universal Joint
Differential Housing
Differential
Drive Shaft
Universal Joint Housing
Steering Knuckle
Wheel Drive Universal Joint
Short Shaft

Fig. 222.—Part Sectional View of the Front Axle of the Four-Wheel Drive Truck Showing Method of Mounting Wheels so that They Combine Directive and Tractive Functions.

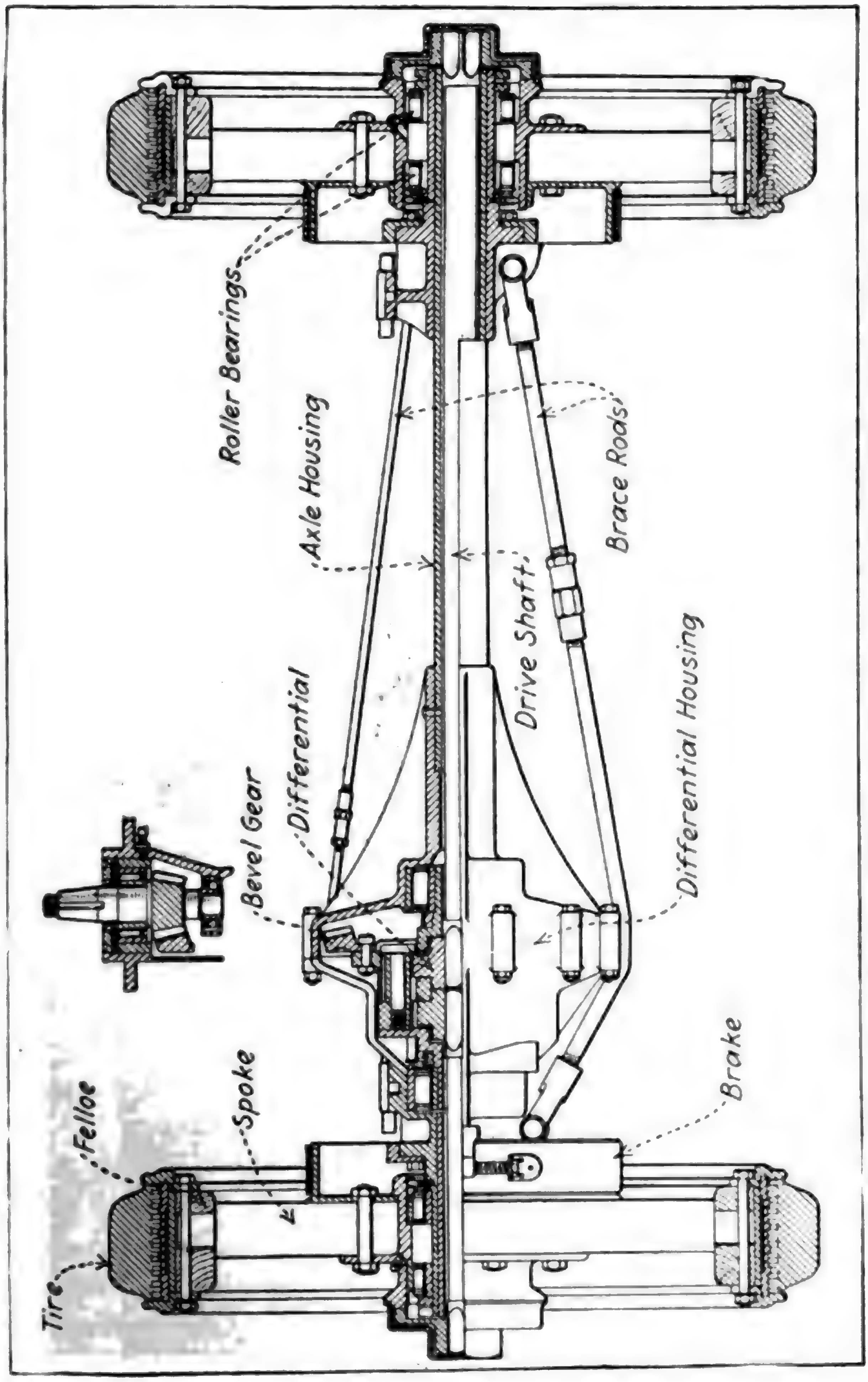

Roller Bearings
Axle Housing
Brace Rods
Drive Shaft
Differential
Bevel Gear
Differential Housing
Spoke
Felloe
Tire
Brake

Fig. 223.—Part Sectional View of Rear Axle of Four-Wheel Drive Truck.

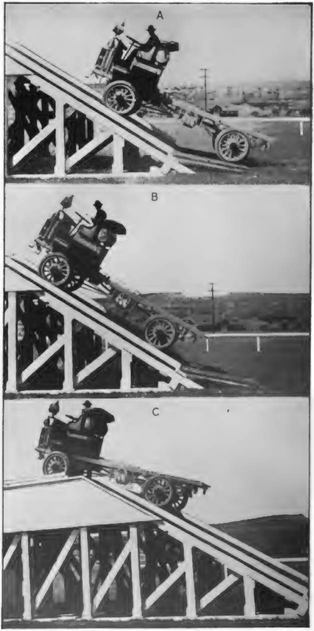


Fig. 224.—Photographs Showing the Test of Four-Wheel Drive Truck on a Special Incline. A—Shows the Start of the Climb. B—Shows the Truck Half-way Up the Incline, and C Shows It Just Going "Over the Top."

not labor at any stage. Mr. Lewis has tried this same feat with many rear-driven trucks, but none have ever succeeded in getting the rear wheels even to the grade. One track-laying tractor did the trick, but could not stop on the incline and start again.

An exact measurement of the platform was made after the performance, and the observers found the base to be 18 feet long, the height of the platform at the top 12 feet, and the slope 21 feet 7⅝ inches. This gives an angle at the base of 33 degrees 41 minutes which, when translated into percentage of grade, gives 66⅔ per cent.

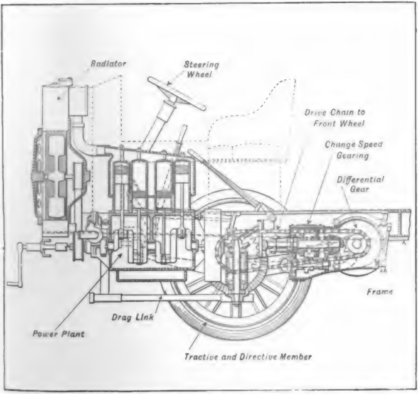

Radiator
Steering Wheel
Drive Chain to Front Wheel
Change Speed Gearing
Differential Gear
Frame
Drag Link
Power Plant
Tractive and Directive Member

Fig. 225.—Sectional View of Front Portion of Foreign Motor Truck Chassis Employing Front Wheel Drive.

Front-Wheel Drive System.—In some forms of vehicles the front wheels only are employed for driving, even when the power is derived from a gasoline engine and transmitted to the wheels by some form of mechanical transmission instead of by a more flexible medium, such as electric current. The front end of a truck of this nature is clearly outlined at Fig. 225, and this is really a tractor that becomes an integral part of the vehicle to which it is joined. The power is derived from the conventional form of four-cylinder water-cooled motor which delivers its power to a gearset combined with a countershaft which is shown in the plan view at Fig. 226. As far as the location of the power plant and gearset goes and the method of coupling these members together, the construction follows conventional practice. The difference is that instead of the drive being from the sprockets at the end of the countershaft member to the rear wheels, the chains go to the front end of the car and drive the front wheels, which form part of an axle of peculiar design.

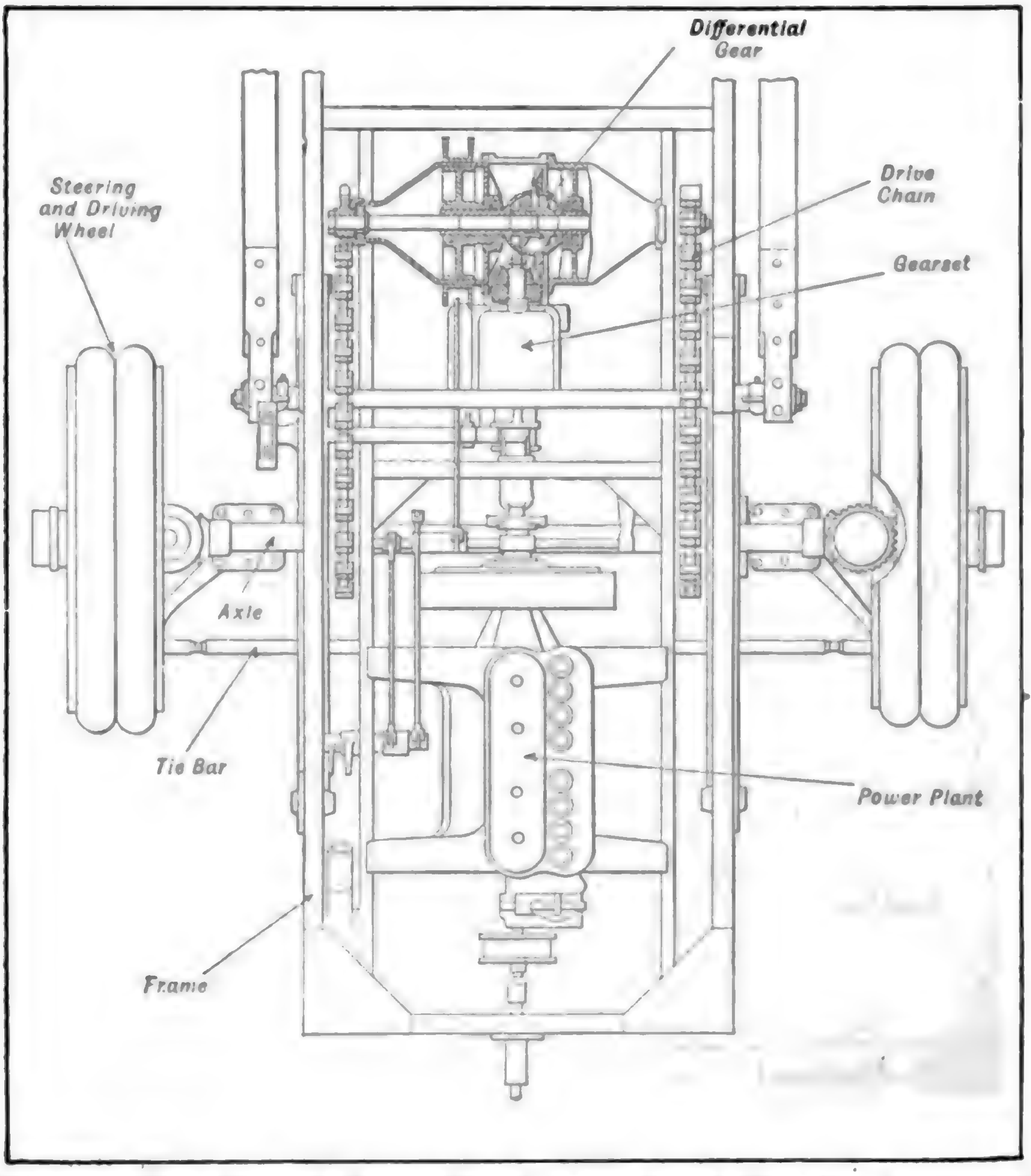

Differential Gear
Steering and Driving Wheel
Drive Chain
Gearset
Axle
Tie Bar
Power Plant
Frame

Fig. 226.—Plan View of Front Wheel Drive Truck Showing Location of Power Plant, Countershaft Assembly and Other Parts.

One end of the distinctive axle construction is shown at Fig. 227, and in this the wheels are mounted in such a way that the steering is not interfered with while the power may be transmitted efficiently, regardless of the degree of inclination of the wheel. The axle consists of a substantial forged member having the wheel carrier mounted in a knuckle of the Mercedes type.

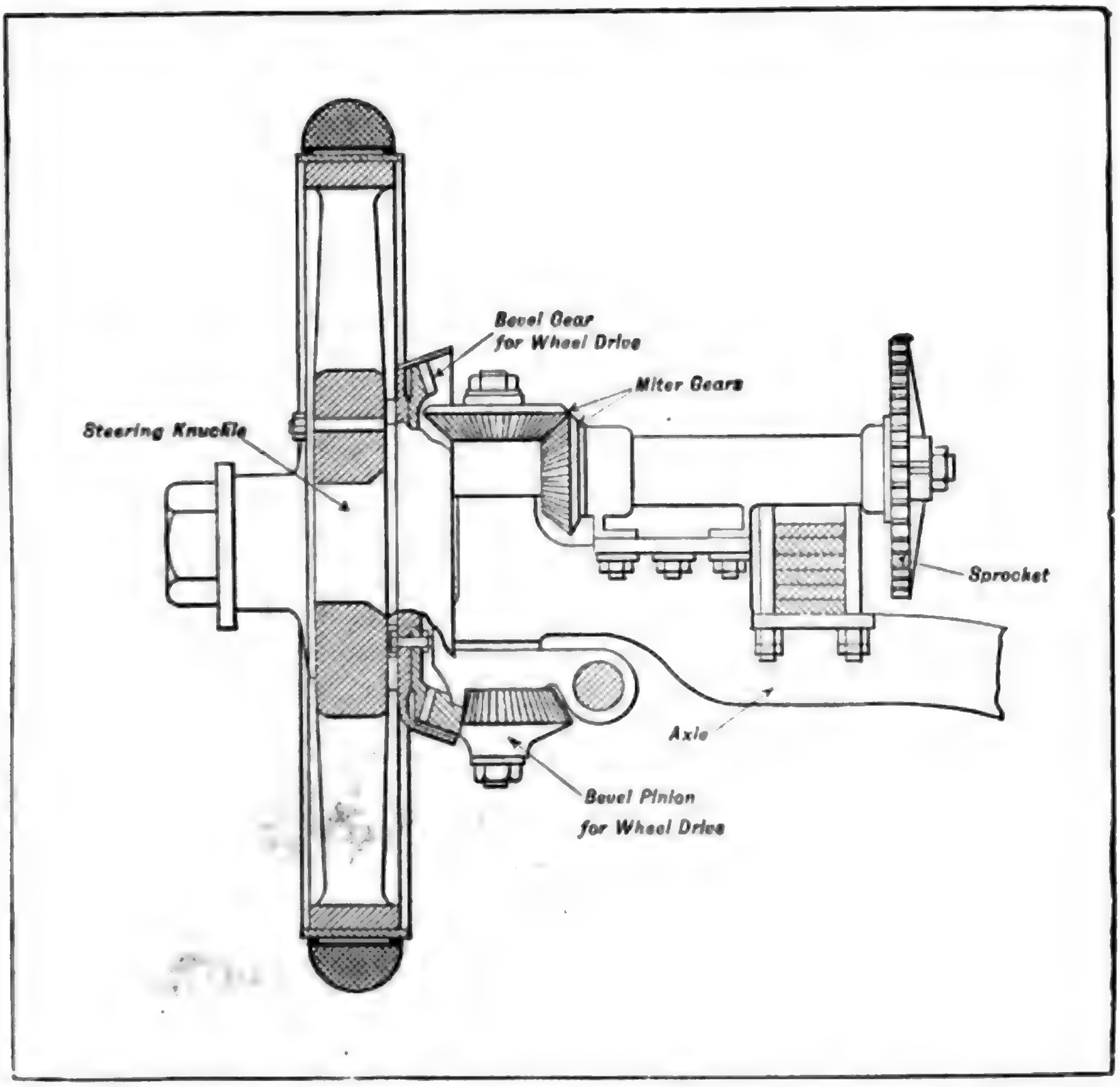


Fig. 227.—How Power May Be Transmitted to Combine Drive and Steering Wheel Without Using Universal Joints.

The knuckle spindle bolt is in reality a driving shaft having bevel pinions at each end. The upper of these bevel pinions is in mesh with another member of the same size carried by a bearing member attached to the axle which serves to support a driving shaft which joins the sprocket at one end to the bevel gear at the other. The wheel is driven by a bevel gear which is rigidly secured to the wheel hub, and which meshes with the bevel pinion at the lower end of the intermediate drive shaft

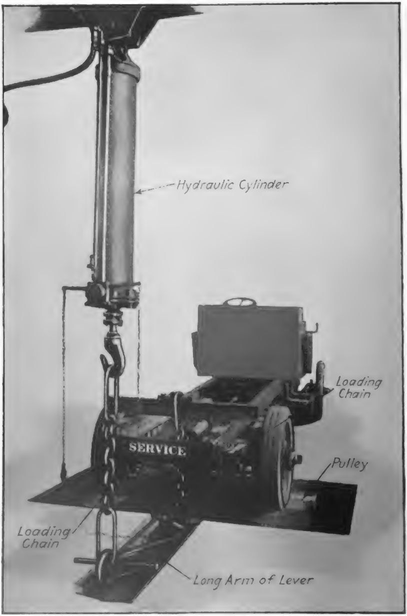

Hydraulic Cylinder
Loading Chain
SERVICE
Pulley
Loading Chain
Long Arm of Lever

Fig. 228.—Special Test Device Used by Service Truck Manufacturers for Giving Chassis the Equivalent of a Road Test Before Delivery.

Google

that forms the steering knuckle bolt. The power is thus transmitted from the sprocket, rigidly mounted on the axle through the medium of the bevel gearing and intermediate shaft to the driving member attached to the wheel hub. It will thus be apparent that the bevel gears on the intermediate shaft transform the rotation of the horizontal shaft to an equivalent rotary movement of the vertical intermediate drive shaft.

With the gear construction described, it will be possible to transmit power without interruption and with no more loss when the wheel-carrying member is at an angle than when it is in the straight-ahead position. When the steering knuckle is turned by the arm bolted to it, which is controlled by the usual form of tie-bar and drag-link, as in conventional constructions, the driving gears do not vary their relationship because the vertical intermediate drive shaft is mounted in such a way that it is independent of the movement of the wheel-carrying member. It is claimed that the opportunity for power loss is considerably less with this system when the wheels are placed at an angle for steering than is the case when the drive is through universal joints. The advantage of driving a vehicle by the front wheels is that liability of skidding is considerably reduced, and that the wheels serve to pull instead of push the vehicle. The front wheel drive system may be applied to chassis forms where it would be extremely difficult to use the rear wheel mechanical drive on account of having a very low carrying platform, as would be the case in vehicles designed to carry bulky merchandise and heavy materials. The front wheel drive system permits one to attach a low gear directly to the tractor frame, and obtain in this way an efficient and effective motor vehicle for carrying heavy loads.

Testing Motor Truck Drive System.—Stationary or "block" testing is considered one of the vital necessities of motor truck engine manufacture. Test rooms are fitted up and machinery installed for the purpose of "running in" each engine "on the block" before it can be considered O. K. for mounting in the chassis. The engine is run on its own power under the observation of engine experts, who detect any defects which may appear, and make the adjustments necessary to secure perfect operation of the engine.

The Service Motor Truck Company not only makes stationary tests of each engine before it is put into the chassis, but it also applies similar principles to the testing of the whole driving mechanism of the truck. At the point in truck manufacture when other makers send their truck out for road test, SERVICE trucks are given the "stationary" road test which enables the expert to detect and correct any faults.

The method of carrying on the test is simple, yet efficient. The truck is driven over a pit in the concrete floor of the assembly building, until the rear wheels of the truck rest each upon a set of two large rollers, as shown at Fig. 228. The forward end of the lever arm, which is shown just back of the truck in the photograph above, is fastened to the frame just over the rear axle by means of chains and wood blocks. To the other end of the lever arm an air hoist is attached and, when all is ready, the hoist exerts a pull on the lever just sufficient to cause a pull-down on the frame equal to the rated load capacity of the truck. The engine is then started and the transmission thrown into gear in the usual manner of starting. The truck remains stationary and the action of the rear wheels is absorbed in revolving the rollers on which they rest.

At this point the action of the truck is closely watched. The axles and springs are under load. The engine and driving members are working against certain resistance. Bearing adjustments are tested, alignment of the wheels is noted, and brake bands are adjusted. If the axle housing gets too warm over any bearing then something is binding, or the lubrication is not satisfactory. If a noise develops, adjustments are made. If a wheel does not run true, it is removed, and many other things are noted which it would be difficult to detect when bumping along the road.

A Six-Wheeled Truck.—The development of the pneumatic tire for motor trucks has had an important influence upon the design of the trucks themselves. One of the problems introduced was how to equip heavy tonnage trucks with pneumatics. The Goodyear Company has produced successful pneumatic truck tires up to and including twelve-inch sizes, the largest size being suitable for the rear of five-ton trucks. The fact that this tire is quite heavy and unwieldy brought about the consideration of the application of four small sizes, instead of two large tires in the rear. This truck and its main features were described in the "S. A. E. Bulletin" by E. W. Templin, and excerpts from his complete article follow:

"It was recognized that, while it is possible to build successfully pneumatic tires up to twenty-inch diameter, it would be useless to build them above twelve-inch diameter if that was the limit permitting of convenient handling in service. The service for which pneumatics could be used, then, would be limited to five-ton capacity trucks. Adapting four tires to the rear of the motor truck, then, opens up the possibility of expansion from five-ton capacity to at least ten-ton capacity.

Dual tires, while successful in a few cases and classes of service, and up to five inches in size, should not be considered for uses on 3½-, 5-, 7- and 10-ton capacity trucks for the following reasons:

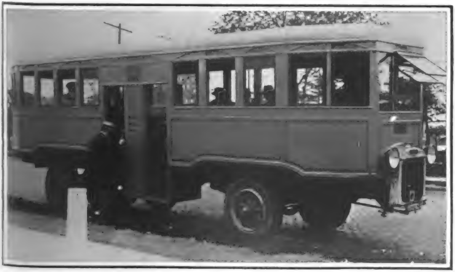


Fig. 228A.—Six-Wheeled Motor Truck Used in Experiments by The Goodyear Company.

1. Inequalities of the road always throw an undue proportion of the load on one or the other tires; therefore, one of them would be carrying more than fifty per cent of the load.
2. In case of puncture all the strain is thrown onto one tire, and the car may be driven for some time without the driver being aware of the puncture, causing the destruction of both tires.
3. In running over rough and stony roads, the chances of picking up rocks and thereby getting bad cuts is much greater than with the single tire.

4. In the case of puncture of the inside tire it is necessary to remove both tires.

5. While it is possible to connect the valve stems of the two tires in order to equalize the air pressure, there would remain the objection that when one of them becomes punctured both would go flat, making it the more difficult to locate the trouble. Also, when striking obstructions, the flow of air from one tire to the other would be too slow to make satisfactory equalization.

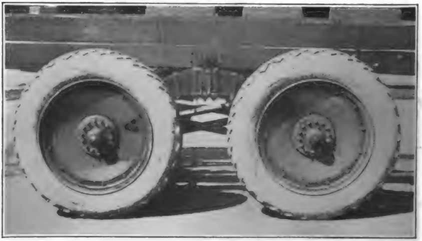


Fig. 228B.—Side View of Rear Truck of Six Wheel Commercial Car Having Four Wheel Drive.

6. Difficulty of getting satisfactory rim equipment.

7. Difficulty of extreme width which puts severe stresses on the axle shaft.

8. Interference of inner valve stem with brake drum.

The other alternative is the application of wheels in tandem to the rear of the truck. Goodyear's first attempt at an application of this kind consisted mainly of an ordinary worm drive rear axle equipped with walking beams at each end, upon which were mounted the four rear wheels, each driven by chain from the main axle.

They were, however, inconvenienced by the chains jumping off, and were not able to get a brake mechanism that would work. The main point against the design was its enormous weight. But it served to show us that satisfactory tire mileage could be secured from such an arrangement, and that there was a good possibility of adapting four small tires in tandem to the rear of a motor truck.

In order to further develop this point, the tandem axle construction shown in Figs. 228B and D, was built. This construction appears to have good possibilities, and has at present operated some 10,000 miles, 2,000 of which were on very severe and rough roads under full load.

Specifications.—Carrying capacity, 5 tons; wheelbase, 180 inches (measured from center of front wheel to center between rear wheels); tires, 40 x 8 inches, pneumatic all around.

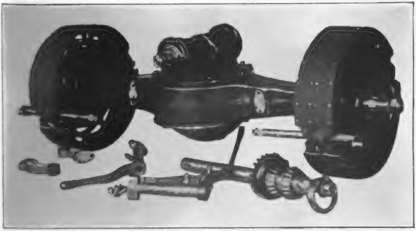


Fig. 228C.—One of the Worm Drive Rear Axles of the Goodyear Six-Wheeled Truck.

Engine: Hercules Model T3, 5-inch bore, 6-inch stroke, 4 cylinders; location, under hood; crankshaft bearings, 5; horsepower rating, 40; torque, 3,200 in.-lb. at 1,200 r.p.m.; cylinders cast in pairs; valves placed on left; water circulation by pump; radiator, Modine "Spirex"; ignition, Eisemann magneto; governor, none: carburetor, Stromberg; lubrication, force feed; motor suspension, 3-point; motor weight, 1,016 pounds; valve diameter, 2⅛ inches; crankshaft diameter, 2⅜ inches; crankshaft bearings (Nos. 1 to 5), 2⅜ x 2¼ inches, 2⅜ x 2¼ inches, 2⅜ x 2¼ inches, 2⅜ x 2¼ inches and 2⅜ x 4 inches; camshaft bearings (front, center and rear), 1¼ x 3 inches, 1¼ x 2¼ inches, 1¼ x 1¾ inches; connecting rod bearings, 2⅜ x 3 inches, 2⅛ x 1⅜ inches.

Transmission: Brown-Lipe Model 60 U.P.P. and auxiliary; Brown-Lipe clutch Model 60, multiple disk type; six speeds

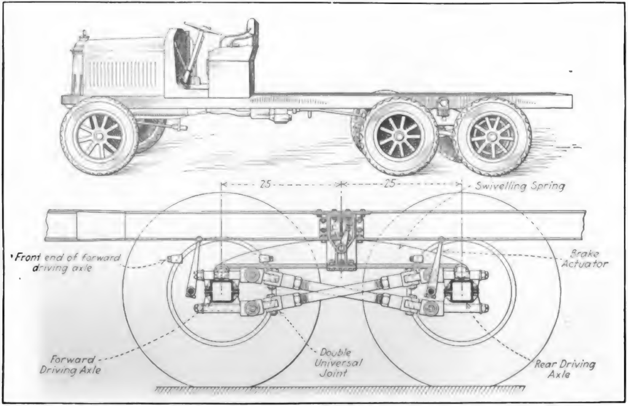

25
25
Swivelling Spring
Front end of forward driving axle
Brake Actuator
Forward Driving Axle
Double Universal Joint
Rear Driving Axle

Fig. 228D.—Side View of Goodyear Six Wheeled Truck Shown in Top View. Detail of Rear Axle Arrangement Shown in Lower Illustration.

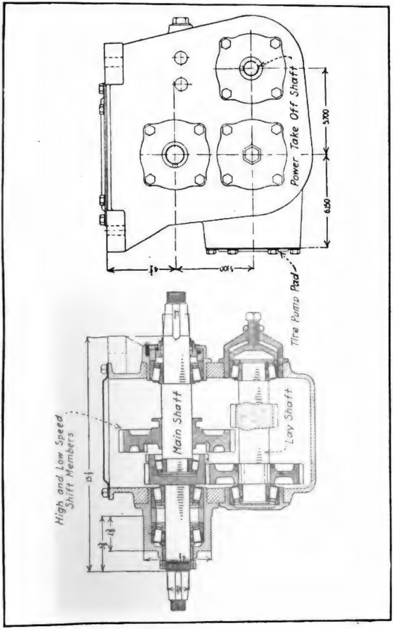

Power Take Off Shaft
Tire Pump Pad
High and Low Speed Shift Members
Main Shaft
Lay Shaft
5.00
6.50
5.00

Fig. 228E.—Details of Auxiliary Gearbox Used in Goodyear Six Wheeled Truck.

forward and two reverse. Gear ratios: Low, 82; second, 35.7; third, 23.2; fourth, 20.1; fifth, 10; sixth, 5.8; low reverse, 99.5; high reverse, 28.4.

With an axle reduction of 5.8 to 1 the low transmission reduction becomes 77.2/5.8 or 13.3; a reduction of 14 to 1 is used. This reduction is difficult to obtain in a conventional type of transmission, so it was decided in conference with transmission builders to use a three-speed unit power plant transmission on the engine and a two-speed auxiliary transmission placed amidships. The construction of the auxiliary transmission is shown clearly at Fig. 228, E.

Goodyear tandem axle drive, using two Stanpar Model 603, worm drive rear axles equipped with 21-inch diameter brakes. Ratio, 5.8 to 1. Torque absorbed in tandem axle assembly. Propulsion is taken by the springs to the frame. There are four brake drums on the rear wheel of each drum, 21 inches in diameter and equipped with two sets of shoes each 2¾ inches wide, which makes a total width of 5½ inches.

Front axle, Standard Parts Co. Model 507. Tire pump, Kellogg Model 42, mounted on transmission. Chassis weight, total, 8,520 pounds; front, 3,810 pounds; rear, 4,710 pounds. Tread, front, 66 inches; rear 61¼ inches. Total weight (loaded): front, 4,520 pounds; rear, 16,500 pounds. Fuel tank capacity, 50 gallons under seat, 17 gallons dash feed tank. Oil tank capacity, 10 gallons under seat. Loading space, 15 feet. Normal motor speed, 1,200 r.p.m. Normal truck speed, 25 m.p.h. Turning radius, 35 feet.

After this truck was built up it was interesting to note whether or not it would perform as expected. Trial runs under full load and limited to 30 m.p.h. maximum speed showed the truck capable of sustaining an average of 21 m.p.h. on the roads between Akron, Canton and Cleveland. In one case the truck became "ditched," but it was able to get out under its own power. In another case the truck pulled out a 5-ton truck stuck at the side of the Cleveland road (under 8½ tons load). The Goodyear truck pulled until the rear wheels slipped on dry brick pavement. In one minute after making this heavy pull the truck was on its way at 25 m.p.h.

CHAPTER VIII

MOTOR TRUCK CHASSIS PARTS

Materials Employed in Frame Construction—Pressed Steel Frames—Towing Hooks at Rear—Design of Leaf Springs—Automobile Suspension Not New—Radius Rods Useful—Alloy Steels for Springs—Attachment of Springs—Fastening Springs to Axle—Overload Springs—Wick Oiling for Chassis Parts—Front Axle Forms—Steering Gears—Worm and Segment Type—Motor Truck Wheels—Demountable Disc Wheels—Steel Truck Wheels—Strength of Wood and Metal Wheels—Wire Wheels—Spring and Resilient Wheels—Advantages of Detachable Wheels—Jaxon Full Floating Wheel—Sewall Cushion Wheels—Forms of Automobile Tires—Construction of Pneumatic Tires—The Cord Tire—Rim Forms—Special Casing Treads—Tools and Supplies for Pneumatic Tire Restoration—Pneumatic Motor Truck Tires—Directions for Application of Truck Tires—Features of Cushion Tires—Forms of Solid Rubber Tires—Installing Solid Tires—Utility of Brakes—Forms of Brakes—Ball and Roller Bearings.

The motor truck chassis is composed of a number of parts distinct from the power plant and transmission groups. The important components are the axles, the steering system, the method of power transmission to the wheels, the design of the frame, and the spring suspension means. The frame forms a connecting link between the motive power and the parts which serve to support the body and machinery. Formerly frames were made in many different styles and a number of different materials were utilized in their construction. At the present time the practice has crystallized to a point where certain construction has been definitely accepted as the best, and this is generally followed in practically all forms of motor cars and trucks. The chassis of the White two-ton truck is shown at Fig. 229, that of the 3½- and 5-ton trucks of the same make at Fig. 230.

Materials Employed in Frame Construction.—The first motor cars were based somewhat on experience obtained in bicycle

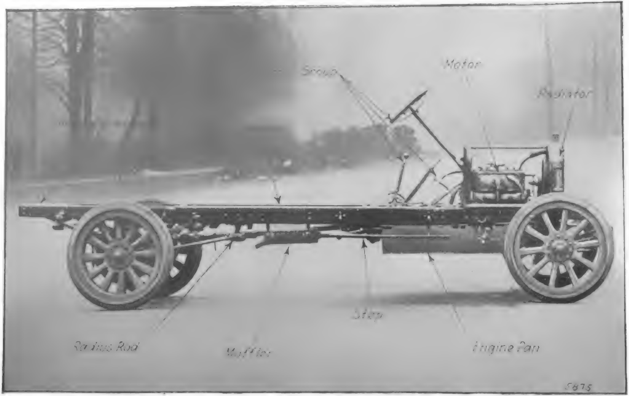

Group
Motor
Radiator
Radius Rod
Muffler
Step
Engine Pan
5875

Fig. 229.—Chassis of White 2-Ton Capacity Truck is Typical of Standard Practice in Motor Truck Frame Construction.

construction, and had frames made of steel tubing. This material was not as suitable for motor car frames as it had been for the lighter two-wheeled vehicles, because the multiplicity of brazed or welded joints necessary made the frame quite a costly and unreliable proposition. Then, again, the round section of the tubing did not offer as easy means of attaching the engine and transmission units as do those frames which are composed of members having a rectangular section. Tubing is used only in subframe work or for bracing members at the present time, and in very few cases.

Following the use of the tubing, automobile builders used angle iron and other structural shapes available on the open market. Other makers used wooden frame members, but at the present time one rarely finds either structural iron or wood used in pleasure cars, though both of these materials have been applied to some extent in motor truck construction. The Franklin Company employs frames on all its models, which are for passenger carrying only, which are made of laminations of specially seasoned and strong wood. The majority of manufacturers, however, favor the use of pressed steel forms, that are not only light and strong, but which have a degree of flexibility which is thought desirable and is not easily obtained with the various rolled structural shapes in iron and steel.

Frames may be divided into several main classes, as follows: Those forms utilizing pressed steel construction, frames built up of iron structural shapes, and combination frames where two or more different methods of construction may be combined. For instance, it is possible to reinforce a wooden frame side member with a strip of steel or iron, or, at the other hand, some makers sometimes fill the channel of a pressed steel frame with wood to strengthen it. Each of these main divisions might be again divided. Wood frames may be made of a solid beam. They may also be composed of vertical or horizontal laminations, the former being preferred. Pressed steel may be made into channels, angles, or modifications of these. The various structural shapes may be utilized in the form of plate, angles, T-rail sections, and I-beams.

Pressed Steel Frames.—A typical pressed steel frame as used on lighter trucks built on passenger-car chassis lines is shown at Fig. 231, and this is the type which is very generally employed. The frame-side members are two pressed steel forms

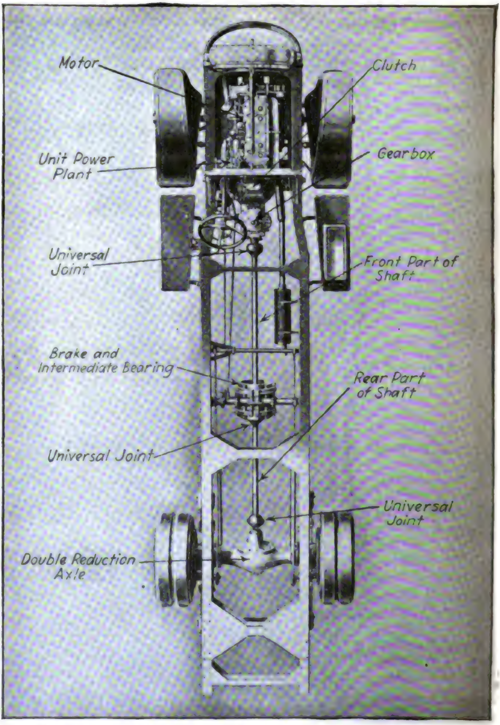

Motor
Clutch
Unit Power Plant
Gearbox
Universal Joint
Front Part of Shaft
Brake and Intermediate Bearing
Rear Part of Shaft
Universal Joint
Universal Joint
Double Reduction Axle

Fig. 230.—Plan View of Chassis of White 3½ and 5-Ton Capacity Trucks.

cambered at the front ends and joined together by a series of three cross braces. The front one serves as a radiator support, that in the center provides anchorage for the torque tube of the axle, while the rear cross member projects on either side of the frame and provides a point of anchorage for the rear supporting springs. The object of cambering the frame members in front is to provide a greater angle of operation for the front wheels and to permit turning on curves of smaller radius than would be possible if the frame members were straight and movement of the wheels limited thereby.

The motor truck frames at Figs. 232 and 233 are also built up of pressed steel side and cross members. That at Fig. 232 is of White construction and has two cross members to support the gearbox. The rear springs are double-shackled. The frame assembly of the Bethlehem truck shown at Fig. 233 is more complete because the brake-actuating rods are shown. A unit power plant is installed in this truck frame, so three points of support are provided as outlined. Attention is directed to the semi-elliptic rear spring supports; these are shackled only at the rear hanger as Hotchkiss drive is employed.

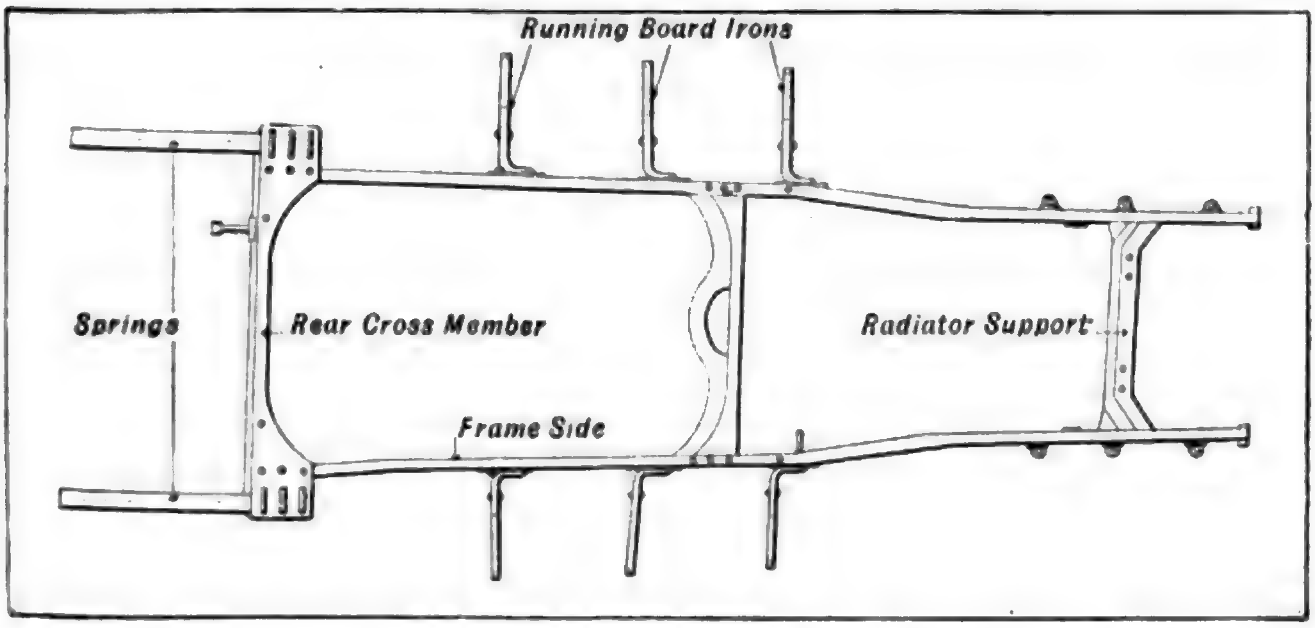


Fig. 231.—Conventional Form of Pressed Steel Automobile Frame with Cambered Side Member at Front End.

Towing Hooks at Rear.—When a motor truck is to be used with trailers, the rear end of the frame should be provided with a special form of spring coupler, or towing hook, and must be braced with substantial pressed steel members extending from the side rails to the rear cross member. The spring absorbs much of the shock incidental to starting a loaded tractor and relieves the frame of some strain. The towing hook shown at Fig. 234 is that provided on Nash truck frames.

Design of Leaf Springs.—The leaf springs used for the suspension of road vehicles consist of several layers of long, narrow

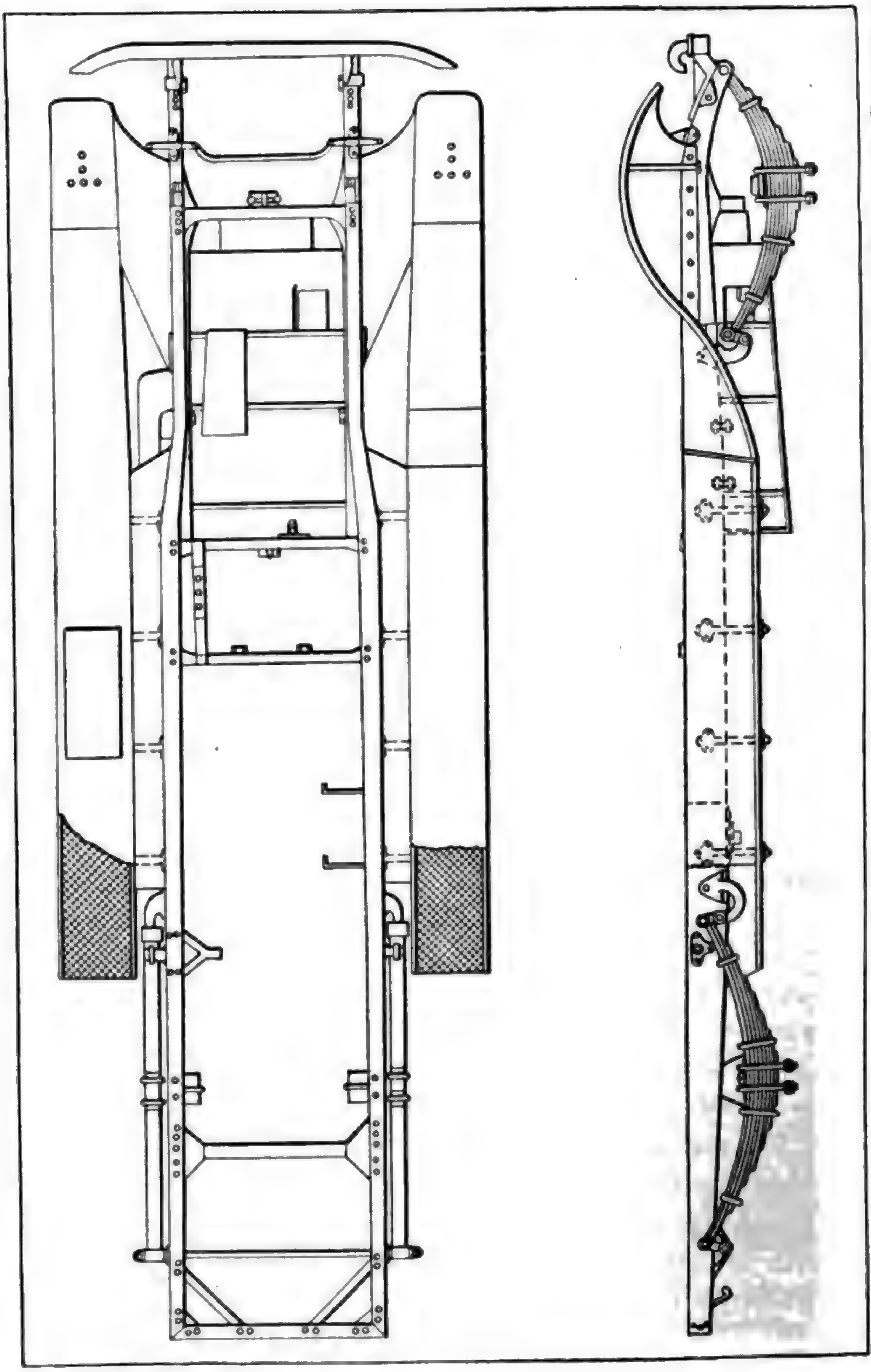


Fig. 232.—Plan and Side Views of Frame of White 2-Ton Truck, Showing Typical Standard Construction of This Important Assembly.

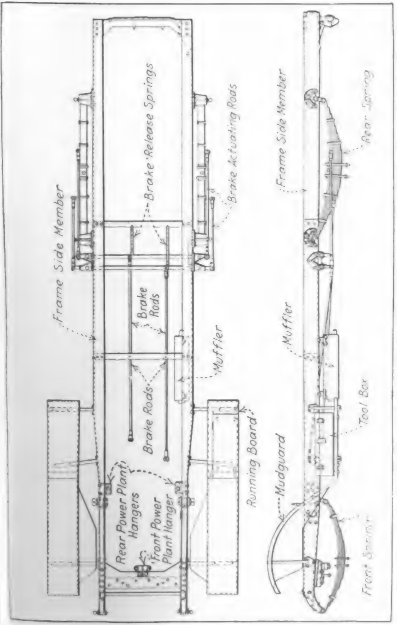

Frame Side Member
Brake Release Springs
Brake Actuating Rods
Brake Rods
Muffler
Brake Rods
Running Board
Rear Power Plant Hangers
Front Power Plant Hanger
Mudguard
Front Spring
Tool Box
Muffler
Frame Side Member
Rear Spring

Fig. 233.—Plan and Side Views of Frame of Bethlehem Motor Truck, Showing All Parts Usually Associated With the Frame Construction.

steel plates so shaped that when laid together they form superimposed arcs of as many circles of large radius as there are leaves. The spring effect is obtained by the elasticity of the metal used, which is increased in value by a process of heat treatment known as tempering. The leaves are usually graduated in thickness, being thicker at the center and tapering from the center to the ends.

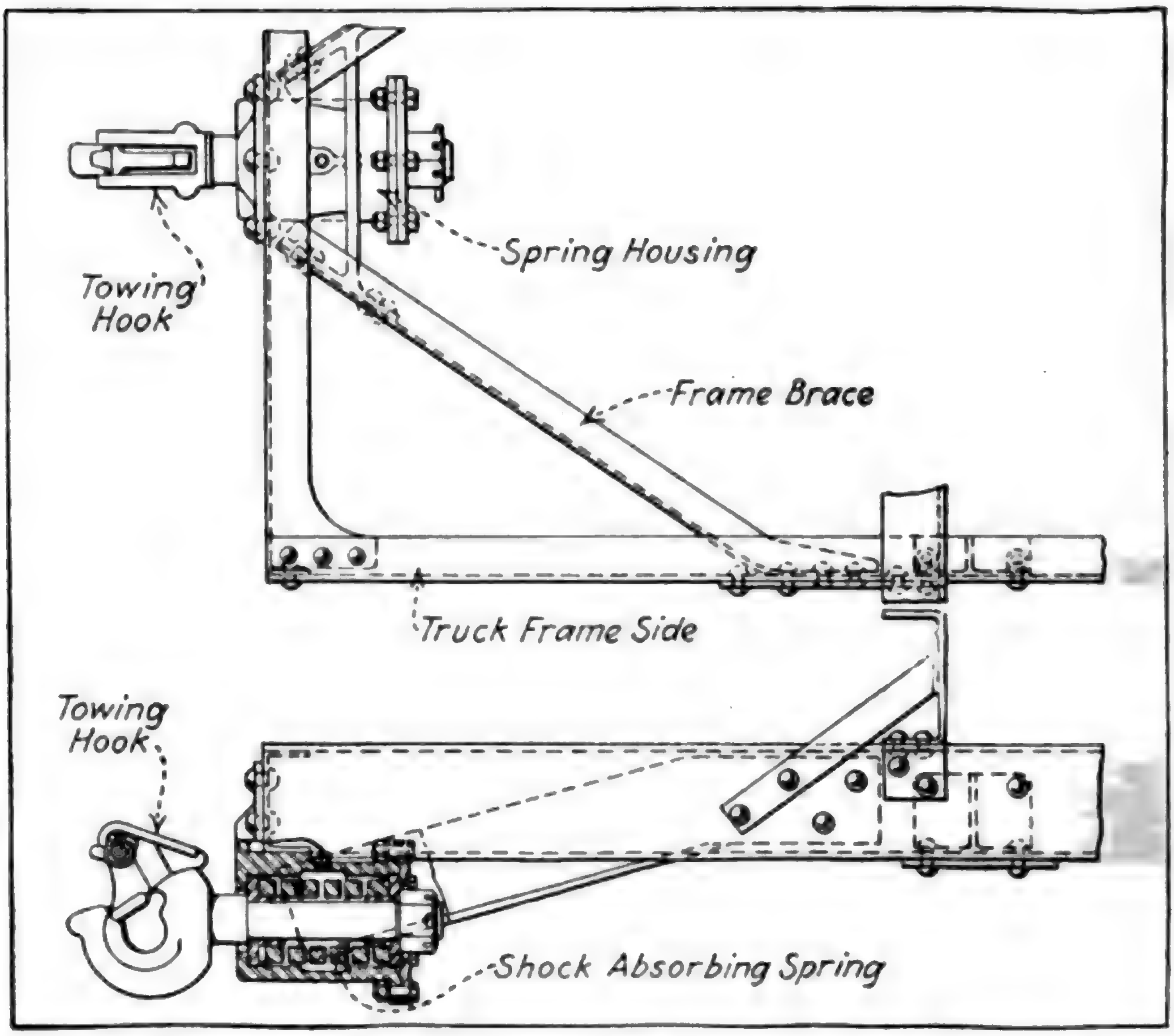


Fig. 234.—Diagrams Detailing Designs of Towing Hook in Rear of Motor Truck Frame.

The reason for following a common line or arc when a spring is composed of more than one leaf is that, as all of the leaves are deflected at once by the load and as the tendency is to straighten out the curved member, they should slide upon one another when altering their shape in such a manner that the leaves will always be in contact with the neighboring leaf at all points. If the curvature of the leaves differed appreciably, the tendency of the plates under load would be to straighten out and separate, and the load would only be carried on those members which were in contact at all points. This would be undesirable because it would cause a loss of spring action and would also result in frequent breakage.

When an automobile chassis is suspended on springs the frame will move in various directions. There is a certain amount of forward and backward end throw, an element of side sway, and the up and down motion caused by the deflection and recoil of the spring. The object of an efficient spring suspension should be to minimize the end throw and side sway as much as possible and yet preserve the freedom of movement of the spring. It is for this reason that the semi-elliptic form is so popular for front suspension on nearly all automobiles and for all-around support on most trucks. It is a stiffer member than the others and is better adapted to carry the weight of the power plant without side sway and to keep the front axle in that relation with the steering mechanism necessary to secure the best action.

Automobile Spring Suspension Not New.—In general, the methods of suspension employed by automobile designers follow closely those that have been used for a number of years by manufacturers of horse-drawn vehicles. When elliptic or semi-elliptic springs of the ordinary description are used one will see that in most light horse-drawn carriages but two are employed, one being placed over each axle and parallel with it. In motor cars one seldom finds a single spring used for suspension at both ends. Usually if one spring is placed in this manner over one of the axles, there are generally two arranged in the conventional manner over the other axle to provide a three-point support. A notable exception is the Ford truck, which employs a single cross spring at each end of the frame.

When only one spring is used in this manner, radius or distance rods are required to maintain a fixed distance between the axle and the frame at the front of the car, and more substantial members of the same character, which will have to take the driving torque effect as well as the braking stresses, will be required for the rear end. This makes two sets of radius rods necessary on each car. Most automobile designers favor the use of two semi-elliptic springs at the front end, because with these there will be no need of using radius rods, as the springs are capable of maintaining the proper relation between the axle and the frame as well as resist the pushing or pulling effect

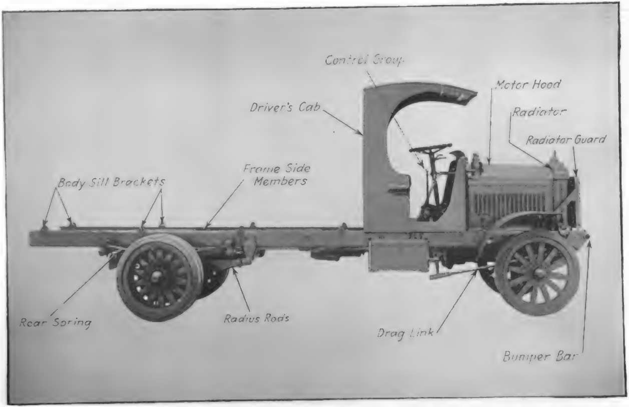

Control Group
Motor Hood
Driver's Cab
Radiator
Radiator Guard
Frame Side Members
Body Sill Brackets
Rear Spring
Radius Rods
Drag Link
Bumper Bar

Fig. 235.—Side View of Selden Truck Chassis Showing Use of Semi-Elliptic Springs and Radius Rods to Keep Rear Axle in Proper Alignment With the Frame.

(depending upon location of shackle) due to vehicle movement, which would otherwise have to be taken by radius rods.

Radius Rods Useful.—With practically all forms of rear suspension, especially in those which utilize the elliptical forms of springs, the inevitable forward throw makes the use of radius rods desirable on heavy cars and trucks, such as shown at Fig. 235, though good results are being secured by using the Hotchkiss drive system with specially designed semi-elliptic springs, as at Fig. 236. It is necessary that the proper distance be maintained between the motor mounted on the frame and the rear axle, where the power is applied to the wheels. The amount of play permissible is governed entirely by the character of the driving system, and with some forms there can be more latitude of movement than possible with others. In nearly all cases, however, it is essential that very nearly a fixed distance be maintained, or there will be injurious stresses on the sprockets, chains, or gears, with attendant loss of power.

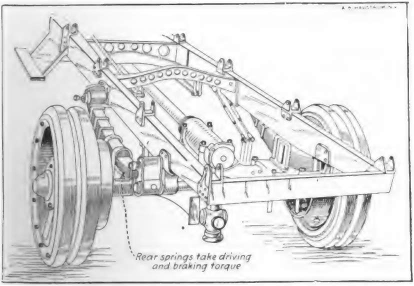


Fig. 236.—Rear End of Truck Frame, Showing Hotchkiss Drive.

Alloy Steels for Springs.—A factor that has become very important is the selection of suitable alloy steels for the construction of the springs. The rapid development of high-powered automobiles which are capable of extremely high speeds had made the development of more resisting and elastic steels imperative, as the open hearth metal of standard analysis used in the manufacture of carriage springs would not make satisfactory supporting members under the severe conditions imposed by the modern automobile. For this reason, various alloy steels, such as vanadium and silicon steel and mixtures of iron, carbon, chromium, and nickel have been developed especially for fabrication into springs.

Among the other functions of springs, they reduce to a certain extent the traction resistance. When the driving wheels meet obstacles the shock produced depends upon the inertia of the axle and that of the wheel which comes into contact with the impending substance plus the resistance of the springs, which factor varies with the elasticity and design. If the springs are not sufficiently resilient the shock will lift a portion of the car as well as the wheel and axle, whereas if elastic members are employed, only the axle and spring will be affected. It is patent that more power is required to surmount obstacles when stiff springs are employed, and part of the power delivered by the engine which might be used to better advantage in propelling the car is absorbed in overcoming the obstacle.

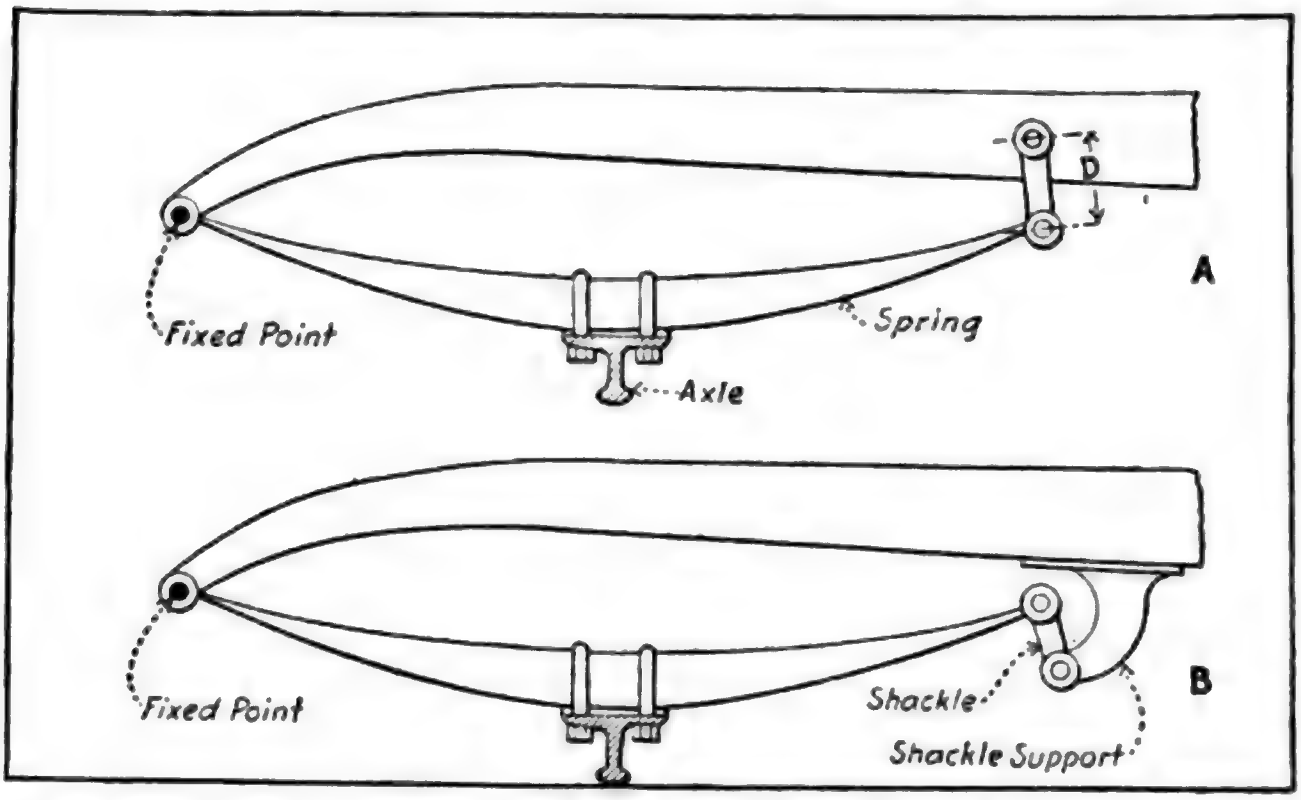


Fig. 237.—Methods of Attaching Semi-Elliptic Front Springs.

Attachment of Springs.—The attachment of springs to the frame and axle is a phase of the suspension problem that is important. The front end of the front springs is usually pivoted directly to the frame in spring horns forming a portion of the frame-side member. The free end of the spring is connected to the frame by a shackle to allow the necessary motion (see Fig. 237, A and B). The rear springs are usually attached to the frame in a different manner than the front member, because to secure maximum efficiency the rear springs should be called upon only to support the load, and they should be relieved of all traction and torsional forces by suitable torque members or radius rods. If springs of the semi-elliptic type are used with radius rods it is advisable to double-shackle them, as shown at Fig. 235. The front suspension of the Selden 3½-ton truck is clearly shown at Fig. 238, which also gives a splendid view of the front axle and method of attaching springs to pads forged integrally with that member.

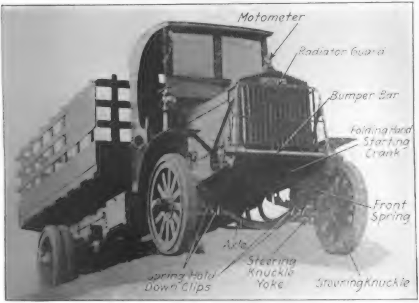

Motometer
Radiator Guard
Bumper Bar
Folding Hand Starting Crank
Front Spring
Axle
Steering Knuckle Yoke
Spring Hold Down Clips
Steering Knuckle

Fig. 238.—Front Suspension of Selden Truck, Showing Axle and Springs.

Fastening Springs to Axle.—The method of fastening the springs to the axle is by means of clips very similar to those that are used in carriage construction, as shown at Fig. 239, B, and Fig. 240, but they are usually heavier and of better material. The spring rests upon a piece of leather or wood placed between it and the supporting pad on the axle, and this material is usually curved enough to conform with the arc of curvature of the spring. This cushion is interposed between the two elements for two reasons, one of these being to avoid the strain which would be imposed upon the spring if attempt was made to attach it directly to the flat or slightly curved spring pad on the axle. The other reason is that the cushion provides a more rigid fastening because there is a certain amount of friction between the spring and the wood or leather piece which prevents slipping of the fastening. Authorities agree that springs should never be fastened by means of bolts passing through the leaves, as this will make a weak place in the spring which may break if stressed unduly at this point.

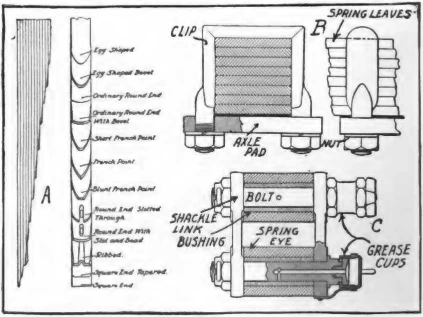

SPRING LEAVES
CLIP
B
AXLE PAD
NUT
A
Egg Shaped
Egg Shaped Bevel
Ordinary Round End
Ordinary Round End With Bevel
Short French Point
French Point
Blunt French Point
Round End Slotted Through
Round End With Slot and Bead
Ribbed.
Square End Tapered.
Square End
BOLT
SHACKLE LINK BUSHING
SPRING EYE
C
GREASE CUPS

Fig. 239.—A—Defining Designation of Finishes of Spring Leaf Ends. B—Showing Construction of Spring Retaining Clip. C—Section of Spring Shackles Using Lubricated Shackled Bolts.

Overload Springs.—In some trucks overload is guarded against to a certain degree by the use of overload springs, as shown at Fig. 241. This is used on International Harvester Trucks, and is extremely simple and effective in construction. A quarter elliptic spring is attached to each side member in such a position that its end will bear on a special pad clipped to the dead axle by a yoke bolt. This is called a "striking block."

When the truck is loaded so the main springs might take a reverse camber when the truck goes over an obstruction or into a "chuck" hole in the road at high speed, the auxiliary or overload springs come into play and relieve the main springs of some of their load, and thus prevent excessive deformation or deflection with a corresponding diminution of the rebound or reaction. The construction, method of attachment and utility is so clearly shown that it calls for no further comment.

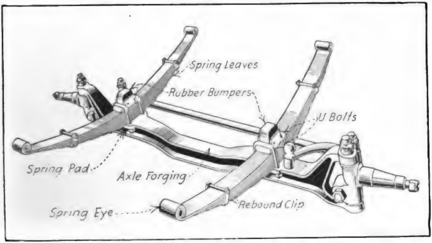

Spring Leaves
Rubber Bumpers
U Bolts
Spring Pad
Axle Forging
Spring Eye
Rebound Clip

Fig. 240.—Typical Front Axle and Spring Assembly for Motor Trucks.

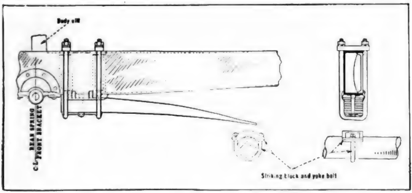

Body sill
C-L REAR SPRING FRONT BRACKET
Striking block and yoke bolt

Fig. 241.—Overload Spring of I. H. C. Motor Truck.

Wick Oiling for Chassis Parts.—For some time past automobile designers have sought to provide some simple form of automatic lubrication system for the usually neglected parts of the car chassis, such as the spring bolts, brake connections, radius rod bolts, spring shackles and other out-of-the-way parts. While oil is not an ideal lubricant for heavily loaded, slow-moving bearing surfaces, it has the advantage over grease of being fed by capillary attraction, while grease needs pressure to force it to the bearings, and if this pressure is not applied, the grease will not flow. The method employed is to cast or otherwise form oil reservoirs integral with the supporting bearings, and to have a wick run from the oil through the hollow bolt or shaft that is to be lubricated, as outlined at Fig. 242. The wick draws up oil constantly which is supplied the bearings by suitable drilled holes in bolt or shaft. Naturally, such a device is automatic in action, and as the reservoir may hold enough

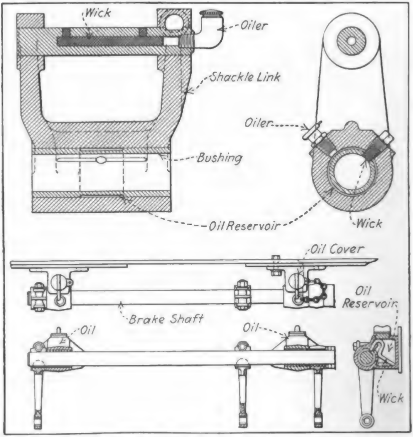

Wick
Oiler
Shackle Link
Oiler
Bushing
Oil Reservoir
Wick
Oil Cover
Oil
Reservoir
Brake Shaft
Oil
Oil
Wick

Fig. 242.—Details Showing How Wick Oiling Is Applied to Motor Truck Frame Parts.

for several weeks' operation, the truck-driver is not called upon to give the oiling means frequent attention and the essential lubricating process is not apt to be neglected. As the parts thus oiled automatically are those that wear out and make noise when the car is operated, any system that insures a regular supply of oil, and consequent diminution of depreciation, is worth while. It is believed that many of the new models will have some such automatic oiling means for chassis parts.

Spring Pin Lubrication.—The new model Bessemer truck is provided throughout with wick oiling reservoirs on all spring pins and also on all four rear shackles, so that instead of turning the grease cup every day and refilling every week, the driver is merely obliged to fill the oil reservoirs once a month. The oiling action is automatic. Additional advantage of wick lubrication is that where grease cups are used, or even liquid lubrication without wicks, a large amount of grit is introduced into the bearings with the grease owing to the fact that the grease cups are always coated with sand and dirt. With the wicks, however, this is of small moment, as the wick acts as a filter and strains out any grit that may get into the reservoir, preventing it from reaching the wearing surface.

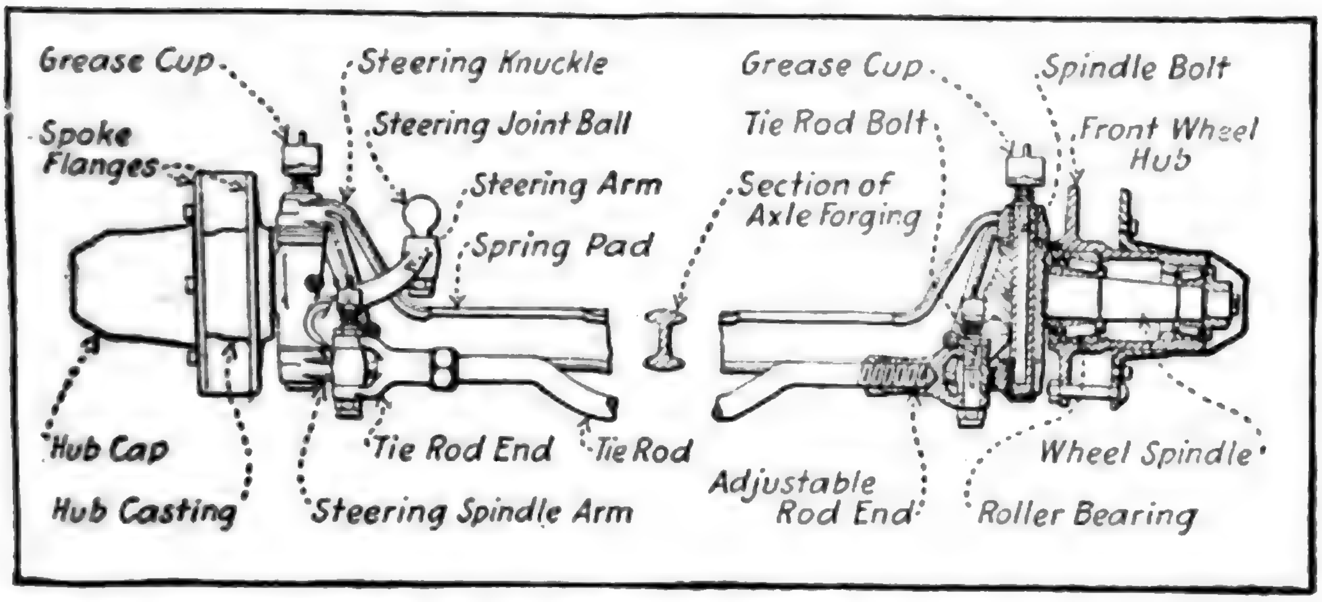

Grease Cup
Steering Knuckle
Grease Cup
Spindle Bolt
Spoke Flanges
Steering Joint Ball
Tie Rod Bolt
Front Wheel Hub
Steering Arm
Section of Axle Forging
Spring Pad
Hub Cap
Tie Rod End
Tie Rod
Wheel Spindle
Adjustable Rod End
Hub Casting
Steering Spindle Arm
Roller Bearing

Fig. 243.—Typical Motor Truck Axle, Showing Use of Roller Bearings in Wheel Hub.

The rear spring shackles are provided with an oil reservoir in the shape of an annular space between the shackle itself and the shackle bushing, as shown at Fig. 242. A lubricator is placed in the top of the bushing barrel for filling, and a wick is situated in the top of the bushing so that as the motion of the truck agitates the oil the wick becomes saturated and so feeds to the wearing surface. In this way lubrication stops as soon as the truck stops and the amount of lubrication will be in direct proportion to the amount of vibration or movement of the shackle, which is what is required.

Front Axle Forms.—Various front axle constructions used in automobiles follow a common design and the same general principle of action prevails in all. Front axles differ from each other only in matters of minor constructional detail, such as the type of steering knuckles used and whether the axle is a one-piece forging or a built-up structure. An axle of good design is shown at Fig. 243. This is composed of a one-piece I-section drop forging of steel which has the advantage of having the steering-knuckle yokes and the spring pads formed integral. This is the type most generally used, because it is exceptionally strong, and when properly designed is not unnecessarily heavy.

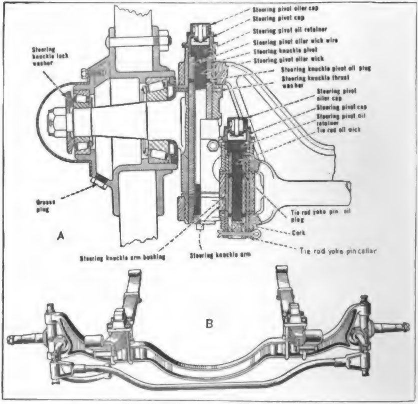

Steering pivot oiler cap
Steering pivot cap
Steering pivot oil retainer
Steering pivot oiler wick wire
Steering knuckle pivot
Steering pivot oiler wick
Steering knuckle pivot oil plug
Steering knuckle thrust washer
Steering pivot oiler cap
Steering pivot cap
Steering pivot oil retainer
Tie rod oil wick
Steering knuckle lock washer
Grease plug
A
Tie rod yoke pin oil plug
Cork
Tie rod yoke pin collar
Steering knuckle arm bushing
Steering knuckle arm
B

Fig. 244.—Sectional View of Steering Knuckle of I. H. C. Truck at A and Method of Installation in Front Axle Shown at B.

One of the front hubs generally used is shown in section in the view of the axle end depicted at A, Fig. 244. The hub is mounted on taper roller bearings, which in turn are supported by the spindle which forms part of the steering knuckle. A long through-bolt passes through the steering knuckle and acts as a bearing for it to swivel on. Steering arms project from each knuckle and are joined together by a tie-bar, as outlined at Fig. 244, B. The axle end at Fig. 245 is that used on Packard motor trucks, and in this case the steering knuckle construction is what is known as an inverted Elliot type. In this construction the yoke is forged integrally with the steering spindle instead of on the axle ends, as at Fig. 244.

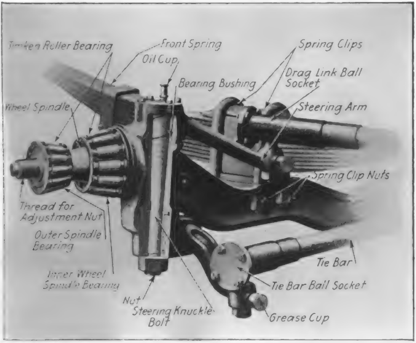

Timken Roller Bearing
Front Spring
Spring Clips
Oil Cup
Drag Link Ball Socket
Bearing Bushing
Wheel Spindle
Steering Arm
Spring Clip Nuts
Thread for Adjustment Nut
Outer Spindle Bearing
Tie Bar
Inner Wheel Spindle Bearing
Tie Bar Ball Socket
Nut
Steering Knuckle Bolt
Grease Cup

Fig. 245.—Steering Knuckle Construction of Packard Motor Trucks.

In order to actuate the steering knuckles, suitable mechanism that will be easily operated must be placed convenient to the driver. The earlier forms of automobiles were provided with forms of tillers very similar to those employed in controlling boats, but while these simple levers gave a certain degree of satisfaction on light cars operated at slow speeds, the development of the heavier vehicles made necessary more easily handled and positive forms of steering gears. The disadvantages of the tiller are that it may be whipped out of the operator's hands by road irregularities, and it is very tiresome to hold because of the continual vibration. It is still used on some electrics.

With the modern forms of wheel-steering devices the hands are always in an easy position, the wheels may be readily operated, and, because of the elimination of vibration by the feature of irreversibility provided by most steering gears of conventional construction, no road shock can loosen the grip of the driver, nor is he fatigued by continued movement of the wheel.

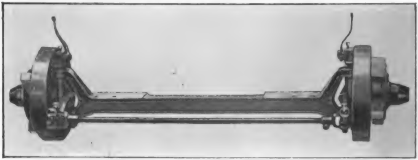


Fig. 246.—Special Front Axle Equipped with Wheel Brakes.

Steering Gears.—Steering gears are made in a variety of forms and all types have their adherents. The accepted construction is clearly illustrated at Fig. 247. In this the steering wheel is attached to a rod which carries a worm at its lower end. This worm meshes with a worm gear, to which a steering arm is attached, and a rotary movement of the hand wheel will produce a reciprocating movement of the steering arm at the lower end of the steering column. The steering arm is coupled to one of the steering knuckles of the front axle by a connecting link, and the movement imparted to the one steering knuckle is transferred to the other one by means of the tiebar which joins them. The parts of the steering mechanism of the White truck are clearly outlined at Figs. 248 and 249. The former shows the worm and sector steering gear; the latter shows the shock-absorbing drag link construction and the ball bearing steering plete with hubs and brake drums.

Some engineers who contended that the worm and sector gear were liable to wear devised combination forms in which a screw and nut principle was combined, the object being to provide a largely increased bearing surface on the threads and gear teeth, and in this manner reduce depreciation. A gear of this type is shown at Fig. 250. The nut or internally threaded member is held from turning by various methods, such as flattening one side and having this in contact with the walls of the casing, by the use of keys or dowel pins, or merely by the pressure of the rack and sector in some of the types. The advantage of this form of steering gear is that it is wholly irreversible and at the same time a minimum of effort is needed on the part of the driver to properly control a very heavy car. The amount of movement of the nut, up and down, is regulated by the pitch and angle of the thread, and its rectilinear motion is transformed into an oscillating movement of the steering arm to which the drag link is secured.

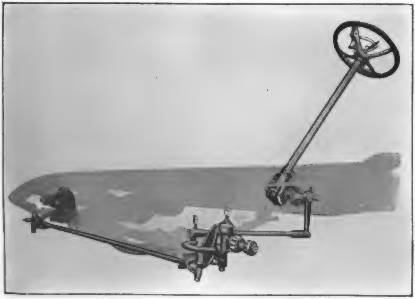


Fig. 247.—How Steering Knuckles are Actuated by Steering Gear by Drag Link.

Worm and Segment Types.—The worm and segment type of steering gear is without doubt the most popular with automobile manufacturers of this country and Europe. It is simple, compact, and positive in action. This type of gear should be maintained in perfect adjustment and be well lubricated at all times.

The greatest defect is the wear that will exist between the worm and worm-gear teeth, and the difficulty of devising any really practical method of taking up the play. The constant oscillations of the vehicle wheels will cause the sector teeth and worm thread to wear at one place, which corresponds to the straight ahead position of the gear.

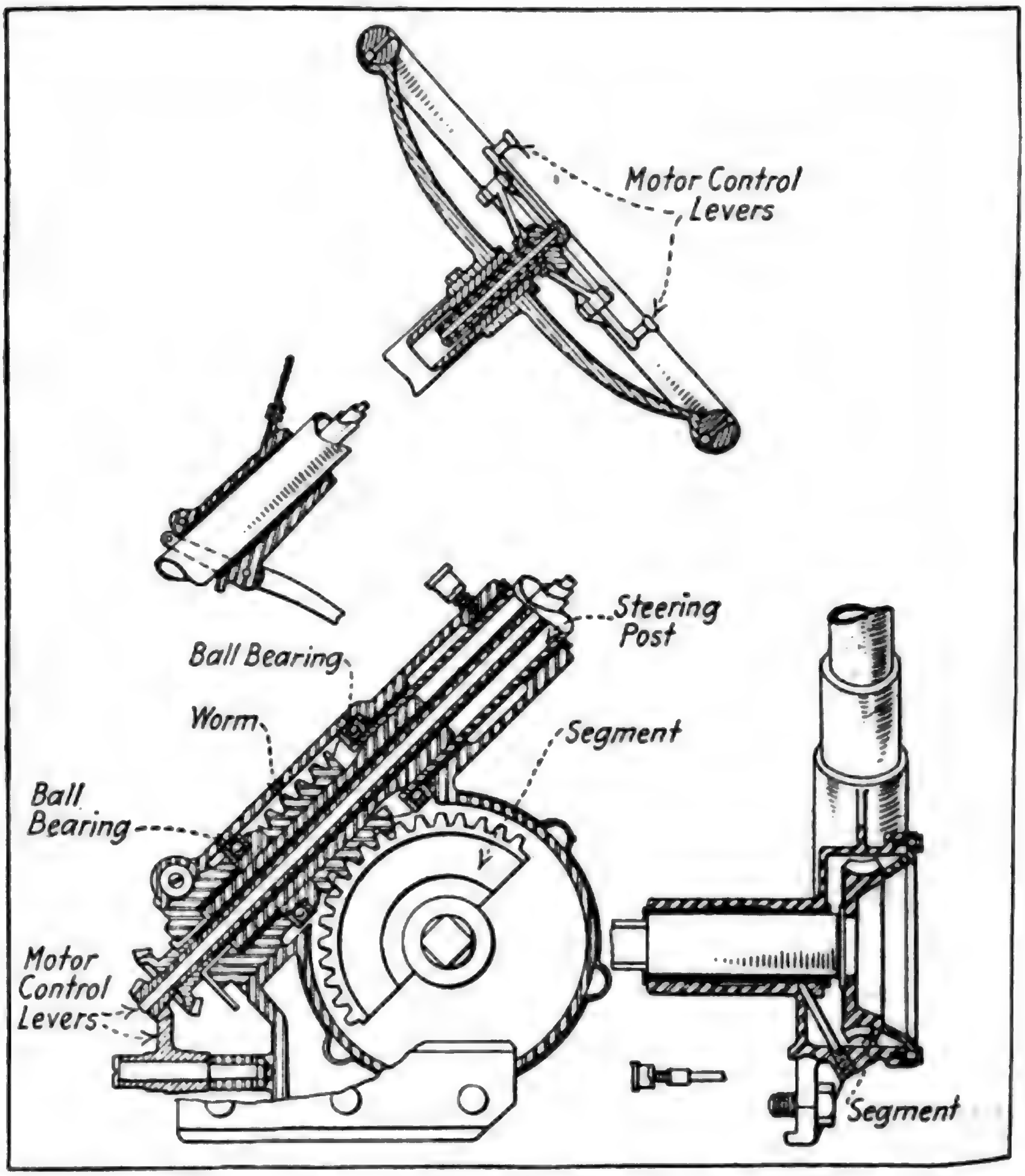

Motor Control Levers
Steering Post
Ball Bearing
Worm
Segment
Ball Bearing
Motor Control Levers
Segment

Fig. 248.—Worm and Segment Steering Gear of White Motor Truck.

This may be taken up in most forms by the use of eccentric bushings in which the sector shaft is mounted, these being moved in such a way that the sector teeth are brought into closer engagement with the thread of the worm. This method is not desirable, because if the eccentric bushings are turned enough to take up the lost motion existing between the teeth, the change in worm-gear position would cause binding between those portions which had not worn as much and which were brought into play only when it was desired to turn the wheels to nearly the extreme angular position. The preferred method of construction is that in which a full worm wheel is used instead of a sector and when wear occurs at one point the worm wheel is removed, the hand wheel and worm are given a complete turn, and the worm wheel is replaced in such a way that a new set of teeth on both worm and worm gear will be in mesh.

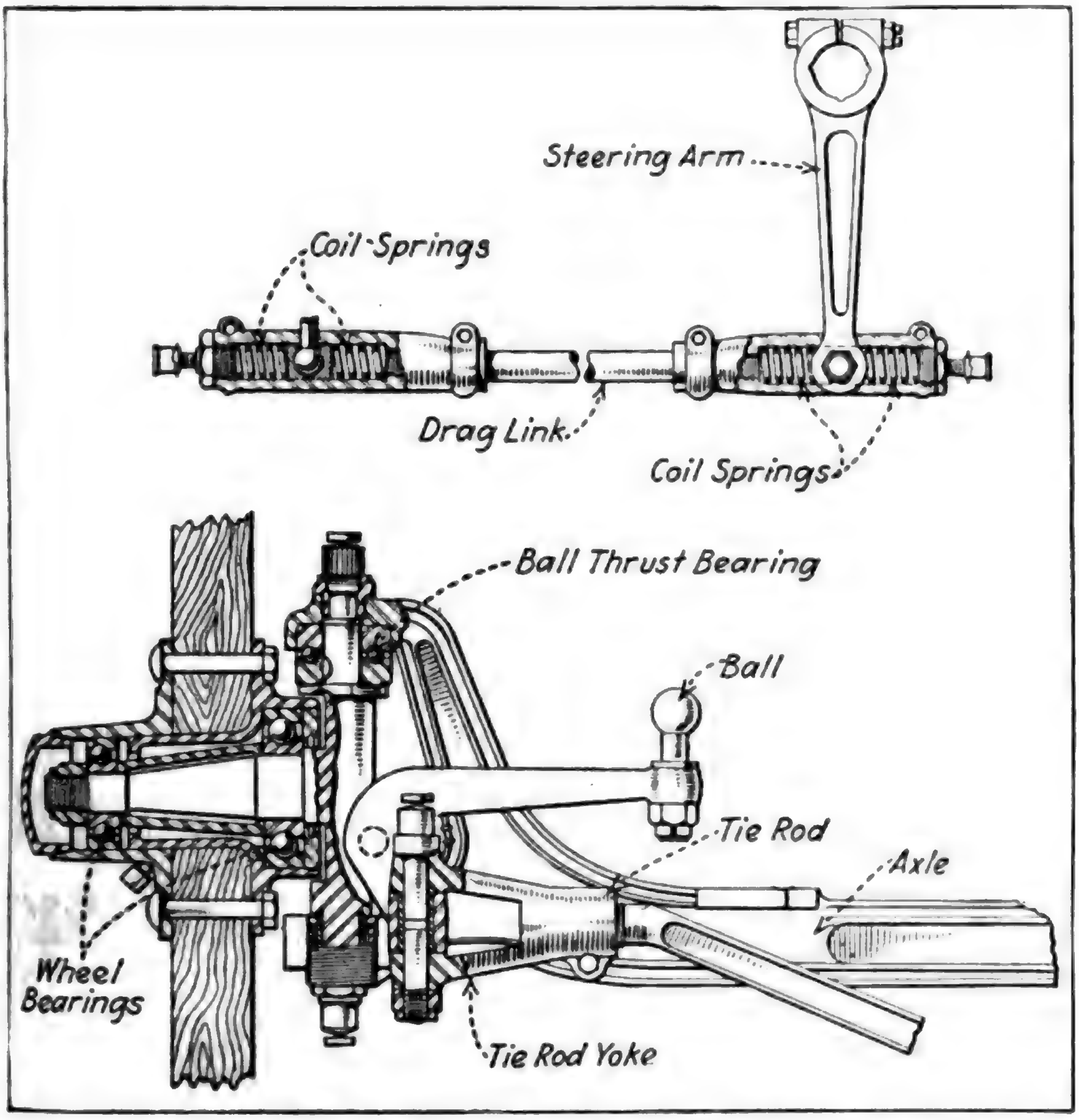

Steering Arm
Coil Springs
Drag Link
Coil Springs
Ball Thrust Bearing
Ball
Tie Rod
Axle
Wheel Bearings
Tie Rod Yoke

Fig. 249.—Drag Link and Steering Knuckle of White Motor Truck.

With all conventional forms of steering gears the object has been to get a complete sweep of the front wheels; that is, to turn them from one extreme position to the other with about

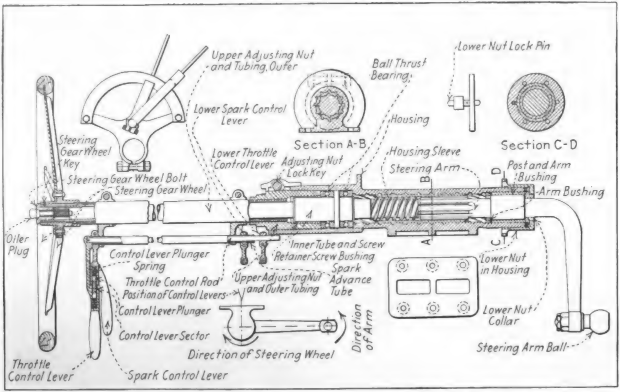

Upper Adjusting Nut and Tubing, Outer
Lower Spark Control Lever
Lower Throttle Control Lever
Adjusting Nut Lock Key
Section A-B
Ball Thrust Bearing
Housing
Housing Sleeve
Steering Arm
Lower Nut Lock Pin
Section C-D
Post and Arm Bushing
Arm Bushing
D
C
B
A
Steering Gear Wheel Key
Steering Gear Wheel Bolt
Steering Gear Wheel
Oiler Plug
Control Lever Plunger Spring
Throttle Control Rod
Position of Control Levers
Control Lever Plunger
Control Lever Sector
Throttle Control Lever
Spark Control Lever
Inner Tube and Screw
Retainer Screw Bushing
Upper Adjusting Nut and Outer Tubing
Spark Advance Tube
Direction of Steering Wheel
Direction of Arm
Lower Nut in Housing
Lower Nut Collar
Steering Arm Ball

Fig. 250.—Diagram Showing Detailed Construction of Screw and Nut Type Steering Gear.

one and one-half turns of the hand wheel. Anything slower than this will be so tardy of action that it will be difficult to steer the car properly and quickly at anything but low speed. On some heavy commercial vehicles, however, it is necessary to provide lower reduction, and two or two and a half turns of the steering wheel are sometimes necessary to produce the proper degree of movement of the front wheels. This is not a point that can be seriously objected to when one considers the low speed of the conventional motor truck, as the operator has ample time to secure any required degree of movement of the hand wheel.

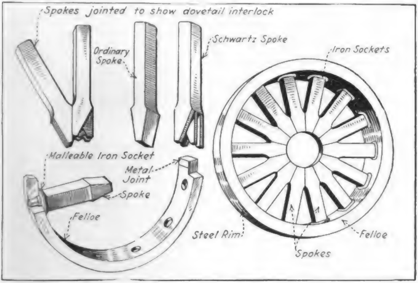

Spokes jointed to show dovetail interlock
Ordinary Spoke
Schwartz Spoke
Iron Sockets
Malleable Iron Socket
Metal Joint
Spoke
Felloe
Steel Rim
Felloe
Spokes

Fig. 251.—Parts of Typical Motor Truck Wheel of Wood Spoke Construction.

Motor Truck Wheels.—The wooden parts of the artillery wheel are depicted at Fig. 251, while the construction of the hub can be very clearly understood by referring to drawings in preceding parts of this chapter. The ends of the spokes which fit between the hub flanges are wedge-shape and are so formed that they will fit closely together when assembled to produce a complete circle of wood which is sandwiched between the wheel-hub flanges, held together by bolts passing through them and the spokes. The outer ends of the spokes are turned down to fit holes bored into the wooden arcs that comprise the felloe. The wheel assembly is held together in much the same manner as that employed in carriage-wheel construction, excepting that the steel rim is usually provided with hook section flanges made to hold the pneumatic tire when that form is used. A complete wooden-wheel assembly minus hub is shown at Fig. 251. This wheel is an excellent construction because the spoke ends fit into metal sockets which are recessed into the felloe. The spoke construction shown is that used on Schwartz wheels; this has a dovetail interlock at the butt ends and makes a much stronger wood wheel. The wood wheels used on the Packard trucks are shown in both front and rear forms at Fig. 252, these being complete with hubs and brake drums.

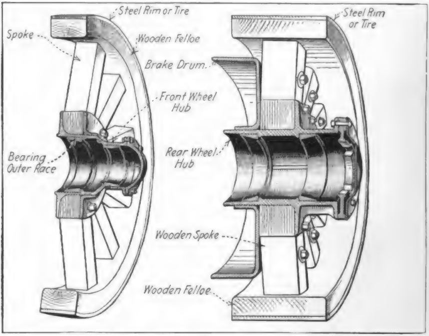

Steel Rim or Tire
Spoke
Wooden Felloe
Brake Drum
Front Wheel Hub
Steel Rim or Tire
Bearing Outer Race
Rear Wheel Hub
Wooden Spoke
Wooden Felloe

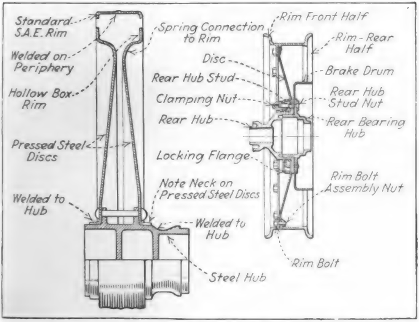
Fig. 252.—Front and Rear Wheel Construction Employed on Packard Trucks.

At the present time automobile engineers seem agreed that second-growth hickory is the only wood that can be used successfully in automobile-wheel construction, but it is becoming more difficult to obtain this material as the production of automobiles is increased. In England the wood is very scarce, so that many designers in that country are turning to the metal-spoke type of wheel. Suitable wood for wheels is not always easy to obtain, because it must be of such a nature that it will stand

Google

both a steady load and sudden shocks. Hickory alone of all common woods combines these two features, and while other trees may furnish lumber that may be stronger or tougher than hickory, in some applications it is the only one which seems to combine the desired qualities.

Metal Wheels a Future Development.—When the supply of wood decreases to a point where it will be difficult to obtain it promptly, it is believed that automobile manufacturers will be forced to use metal wheels. This is being done by some of the producers of heavy commercial cars in numerous instances, and the metal wheels which have been applied may be divided into three types. Those used on the heavier vehicles may be of cast steel, having a spoke and hub construction very similar to that of the present-day artillery wooden wheels, except that the hubs and rims are cast integral with the spokes. This forms a very strong wheel assembly; the only objection that can be advanced against them is that while stronger than wooden wheels they are heavier. Metal wheels are sometimes made by fastening two steel stampings together to form the rim and web portions, these


Standard S.A.E. Rim
Welded on Periphery
Hollow Box Rim
Pressed Steel Discs
Welded to Hub
Spring Connection to Rim
Disc
Rear Hub Stud
Clamping Nut
Rear Hub
Locking Flange
Note Neck on Pressed Steel Discs
Welded to Hub
Steel Hub
Rim Front Half
Rim-Rear Half
Brake Drum
Rear Hub Stud Nut
Rear Bearing Hub
Rim Bolt Assembly Nut
Rim Bolt

Figs. 253 and 254.—Metal Wheel at Left Is Built Up of Two Discs. Metal Wheel of Single Disc Type Shown at Right.

in turn being joined to a separately formed flanged hub members, as shown at Fig. 253.

Demountable Steel Disc Wheel.—A disc wheel of great simplicity that has many of the advantages of the quick demountable wire wheel and which is much simpler in construction and easier to keep clean is depicted at Fig. 254. But a single disc is used, this being a special form so that the disc is thickest at the center portion where it is attached to the hub and thinnest at the edge where it is attached to the tire-carrying rim. The outer edge of the disc can be fastened to any desired design of felloe band and can be made to carry any type of rim. It is installed on a master hub by clamping it between two plates, driving lugs or dowel pins being provided to drive the discs.

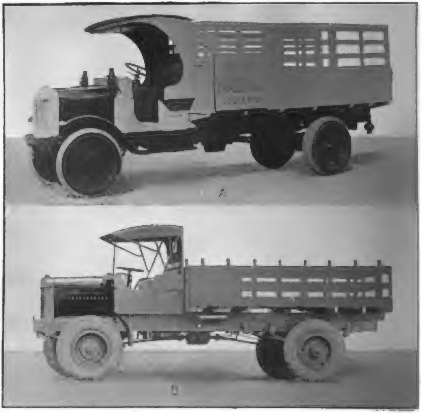


Fig. 255.—Truck at A. Is Equipped with Stamped Steel Disc Wheels. The Wheels at B are Cast Steel Construction.

The construction of the master hub is such that the outer flange bears tightly against the disc and is provided with a series of simple retention bolts to prevent it from backing off. The whole wheel may be taken off much easier than the usual form of demountable rim. The wheels are mounted on the axle with a concave side facing out and it is said they do not have the clumsy look that disc wheels mounted in the opposite way have. Many engineers believe that the disc wheel will be the ultimate type for automobiles, and as a dished disc of the tapering section and form outlined has great strength and will be very easy to keep clean, it is reasonable to expect a wider application when the motoring public becomes accustomed to the unconventional

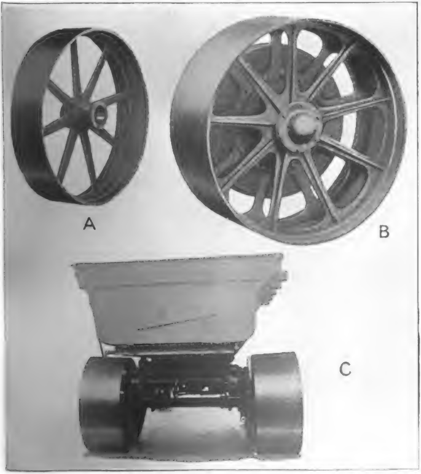


Fig. 256.—**Cast Steel Wheels are Used on White "Good Roads" Truck.**

appearance. A truck equipped with pressed steel disc wheels is shown at Fig. 255, and as will be evident, they are very neat in appearance.

Steel Truck Wheels.—In a paper read before the S. A. E., P. Klinger presented some interesting facts relative to steel wheels for motor trucks and what is required in their design. In part he said: "The design must be such that vibrations resulting from road shocks are not concentrated at any point but distributed over, or dissipated throughout, the entire wheel structure; otherwise metal fatigue eventually results. Materials having a low elastic limit are not suitable for truck wheels any more than malleable or wrought iron is for vehicle springs, as a successful metal wheel must have a certain degree of resiliency. Many of you have, no doubt, had experience with the early designs of built-up metal wheels and are well acquainted with the difficulties of loosened rivets and bolts, also with cracks developing in some types of cast disc and spoke wheels.

Various essential and fundamental metal casting principles have not been recognized in the design of some cast metal wheels, such as the fact that all steel or iron castings are composed of crystals which are formed as the metal cools and run as consistently as the fibers in wood. Just as the weak spots in wood are where the branches run out, so the weak spots in castings are found where right-angled joints occur. Crystals form regularly at right angles with the contour of the castings, and where sections meet at right angles two crystal formations join and there is a resulting line of weakness. To overcome this tendency heavy fillets have been used at intersections, but the added mass of metal usually causes shrink-holes and consequent weakness.

A hollow-spoke hollow-rim construction with a semi-flaring attachment to the rim is a partial recognition of this fundamental feature, but a full realization of it is attained only by the hollow-spoke wheel, where the spokes join the rim in broad sweeping curves, giving an arch-like support to the rim, at the same time avoiding objectionable crystalline formation and placing the metal so that the high elastic quality of steel is utilized somewhat in the form of a spring instead of as a dead strut, as is the case of the straight spoke of either cruciform or U-section and also very largely with the hollow spoke with the semi-flaring connection to the rim. Some disc wheels have cracked around the hub as well as near the rim. When spoke wheels have cracked it has been almost invariably in the spoke near the rim or in the rim near the spoke, but this has not occurred in wheels having the broad flaring connection between the spoke and the rim."

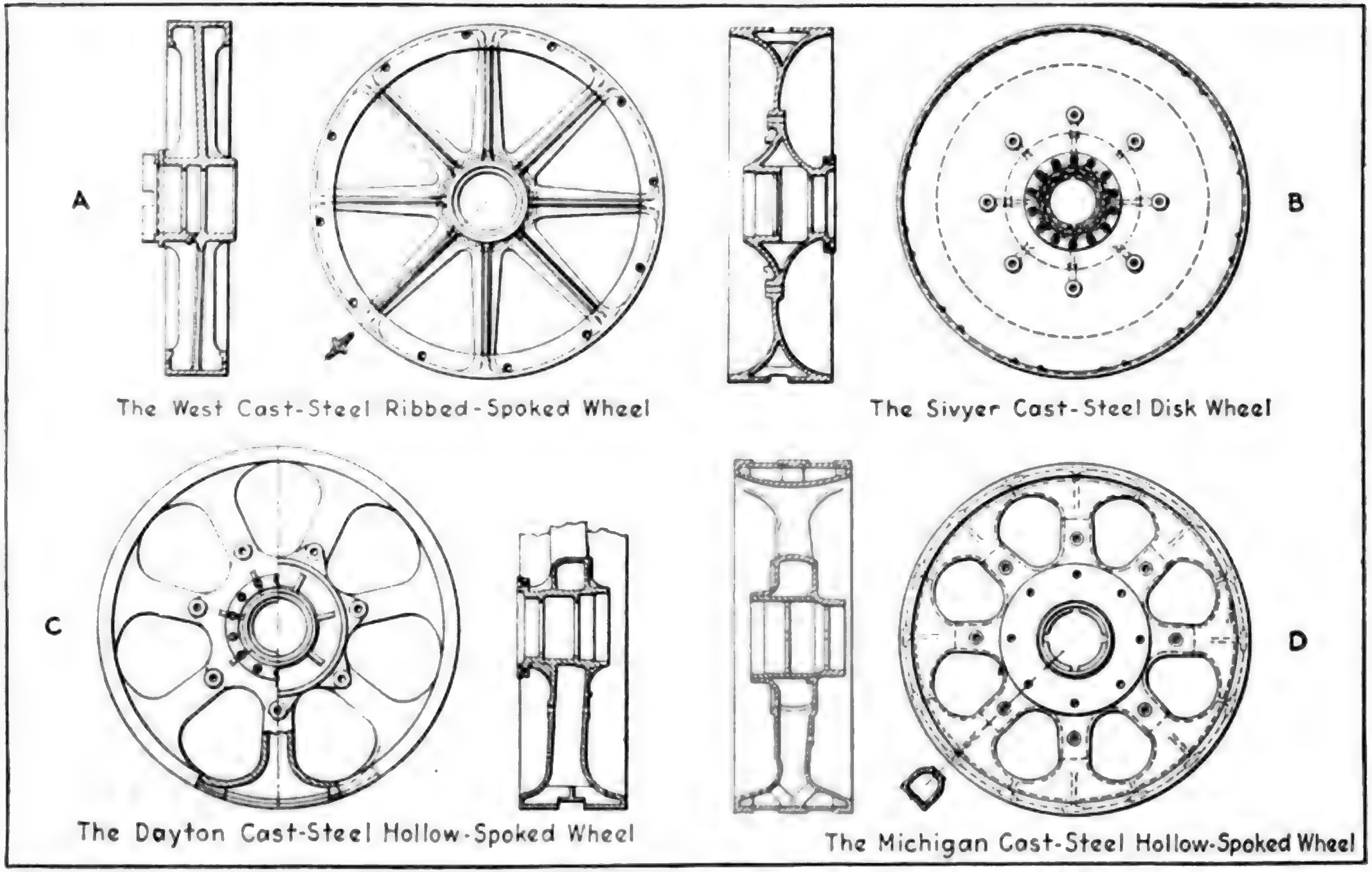
WEIGHTS OF DIFFERENT METAL WHEELS

	36 by 5 Front	40 by 5 Dual	Set
Cast-Steel Hollow Flaring Spoke Integral-Hub Wheel	130 Lbs.	269 Lbs.	798 Lbs.
Hubless Type Metal Wheel with Hubs and Bolts	158 "	319 "	954 "
Pressed Steel Built-up Wheel.......	131 "	275 "	812 "
Wood Wheel with Hubs and Bolts..	116 "	336 "	904 "

"For the large-size pneumatic truck tire equipment most of the tire companies favor metal wheels and a number of different satisfactory types have already been made. So far as my knowledge goes, these have not been given careful laboratory tests but have withstood strenuous service tests, such as driving at speeds as high as 45 miles per hour on three-ton trucks, and withstanding tire inflation of hydraulic pressure as high as 390 pounds per square inch on a 44 by 10 cord tire. A metal wheel enables a demountable rim to be used with a wheel rim having an open slot for the valve stem, thus eliminating any lifting of the tire and rim when applying. The apparent increasing tendency to use some type of internal drive will do much to increase the metal wheel demand because of the better maintenance of gear mesh with the use of integral-hub metal wheels. Consistent cooperation between the foundryman and truck engineers has done and will continue to do much toward the satisfactory service to be realized from metal wheels, and the price question will be largely solved by standardizing of designs with consequent quantity production."

Strength of Wood and Metal Wheels.—As to comparative strength, the table on page 407 gives the results of tests made by a recognized testing bureau on wheels designed for the same truck using 36 by 5 front and 36 by 10 rear wheels.

It should be noted that the wood wheel was not loaded above 0,000 pounds as the speed of deformation indicated an approach to the yield point. The pressed steel built-up type front wheel



The West Cast-Steel Ribbed-Spoked Wheel

The Sivyer Cast-Steel Disk Wheel

The Dayton Cast-Steel Hollow-Spoked Wheel

The Michigan Cast-Steel Hollow-Spoked Wheel

Fig. 257.—Types of Cast Steel Wheels for Motor Trucks that Have Received Practical Application.

yielded beyond the range of the instruments of 40,000-pound loading, and the rear at 75,000-pound loading required almost the extreme instrument range. The relatively slight permanent set and the great resistance to side-thrust in the case of the cast-steel wheels, and especially in the hollow full-flaring spoke type, should also be noted.

STRENGTH TESTS OF METAL WHEELS

36 by 5 Front Wheels

Type	Weight, lb.	Maximum Radial Load Applied, lb.	Deformation at Maximum Load in.	Permanent Set at Maximum Load in.	Ultimate Side Thrust Loading, lb.
Pressed Steel, Built-up	147	40,000	.....	.....	30,500
Malleable Iron	147	60,000	0.0677	0.0259	27,600
Cast Steel Disc	169	60,000	0.0359	0.0187	48,100
Cast Steel, Hollow Rim, Hollow Flaring Spoke	100	60,000	0.0645	0.0220	49,200
Wood		Front Wheels Not Tested			

36 by 10 Rear Wheels

Type	Weight, lb.	Maximum Radial Load Applied, lb.	Deformation at Maximum Load in.	Permanent Set at Maximum Load in.	Ultimate Side Thrust Loading, lb.
Pressed Steel, Built-up	341	75,000	0.4153	0.3425	43,200
Malleable Iron	266	100,000	0.1928	0.1180	42,500
Cast Steel Disc	268	100,000	0.0881	0.0261	75,500
Cast Steel, Hollow Rim, Hollow Flaring Spoke	286	100,000	0.0513	0.0113	101,000
Wood	252	60,000	0.1082	0.0336	43,700

The various types of metal wheels that have been developed are shown at Fig. 257. At A, the spokes have a cruciform section. At B, the hub and rim are joined by a solid web or dished plate. The forms at C and D have cast steel hollow spokes and felloes.

Wire Wheels.—The metal wheel most generally used now on passenger cars, however, is a strengthened and modified suspension type so commonly used in bicycle and motorcycle construction. In this the steel hub member is joined to the outer rim by spokes of steel wire interlaced in such a manner that they hold the hub and rim together firmly. One advantage of metal wheels is that this material may be worked up into any desired form, and, where lightness is desired, one can use wire-spoke wheels and either the built-up pressed-steel forms or the cast-steel wheels for heavy loads. If lightness is desired, light metals

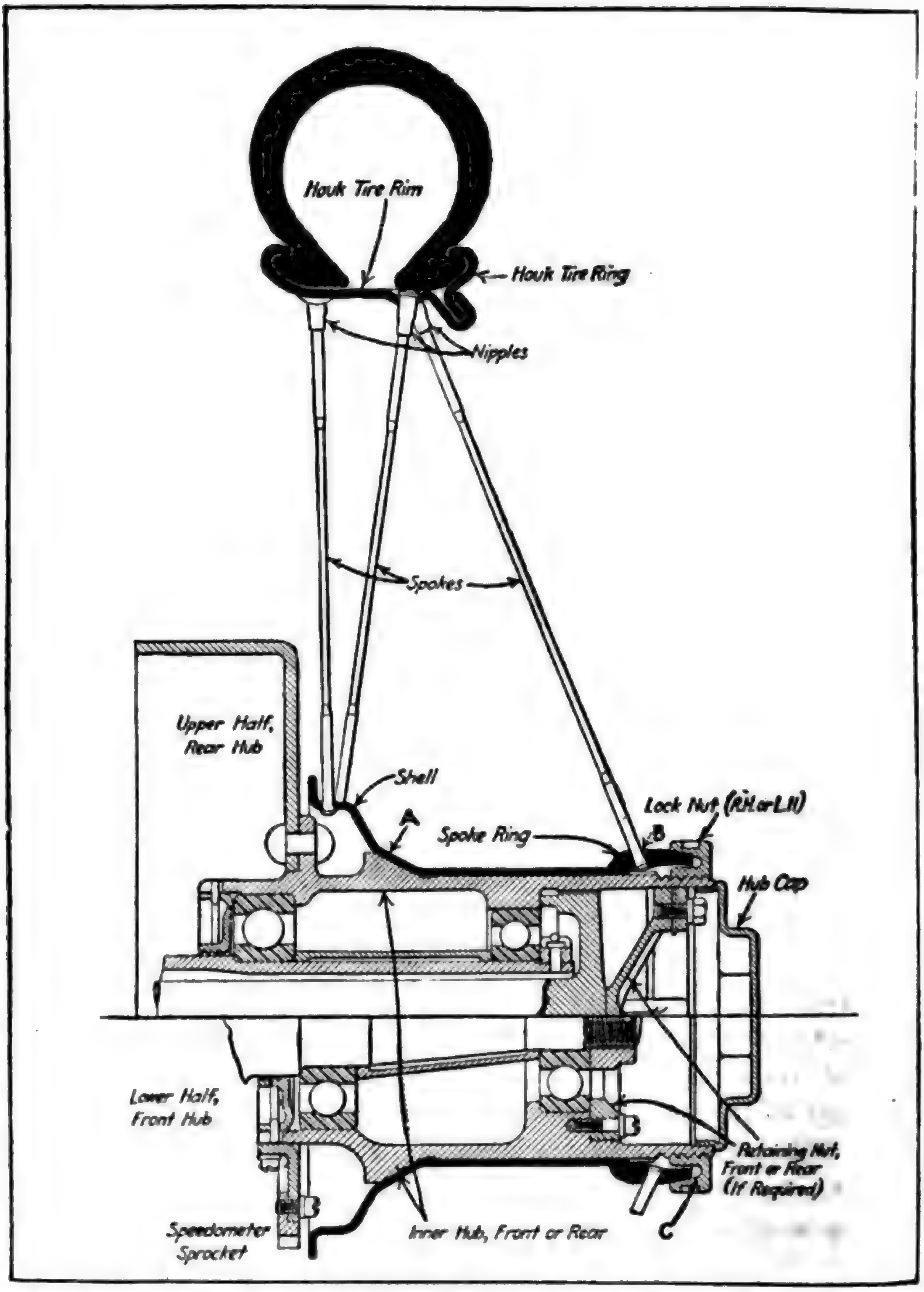

Houk Tire Rim
Houk Tire Ring
Nipples
Spokes
Upper Half, Rear Hub
Shell
A
Spoke Ring
Lock Nut (R.H. or L.H.)
B
Hub Cap
Lower Half, Front Hub
Retaining Nut, Front or Rear (If Required)
Speedometer Sprocket
Inner Hub, Front or Rear
C

Fig. 258.—Sectional View Showing Construction of Triple-Spoke Rudge-Whitworth Detachable Wire Wheels. Rear Wheel Hub-Section Shown Above Center Line, Front Wheel Hub Section Depicted Below It.

which are very strong are available, while maximum strength is obtained by the use of the highly resistant materials in the cast form.

The wire wheel has attained considerable popularity in America for passenger cars, but it has not been applied to trucks because the more substantial and simpler disc and cast metal forms answer every truck requirement. In its improved forms it has much to commend it for light automobile service. The wire wheel is lighter than a wooden wheel of equal strength, there being a saving of at least 33⅓ per cent of weight when wire wheels are employed instead of the artillery type. Advocates of the wire wheel state that it is stronger than the wooden wheel in both vertical and horizontal directions. In a wooden wheel the load is carried on the spokes which are under compression, whereas in a wire wheel the weight is carried by the spokes which are under tension. A typical wire-wheel assembly is shown at Fig. 258, this being a form used to a large extent on touring vehicles in this country.

It is a well-known fact that the friction between tire and road generated in driving a car at even a reasonable speed results in quick and excessive heating of the tire structure. In the wooden wheel, which serves in a sense as insulation, there is a very slight ability to quickly dissipate heat. Metal wheels requiring only a thin metallic rim, the spokes serving, in a sense, as additional cooling surfaces, will dissipate this heat almost as quickly as it is generated. This results in keeping the tire at almost normal temperature even in very warm weather.

Spring and Resilient Wheels.—Attempts have been made to build wheels which would have some form of flexible or yielding member to join the rim and the hub, instead of the rigid wood or metal spokes. Many spring wheels have been evolved, the ultimate aim of all inventors of this form being to provide a supporting member that would have sufficient resiliency so the air-filled tire could be dispensed with and its troubles eliminated.

The Lipkowski spring wheel is depicted at Fig. 259, this being a fairly good example of the radial coil-spring form which is said to have given fairly satisfactory results in its trials. In this construction the hub and felloe are composed of two members held together by bolts. These retention members form the journals for the loops on the end of the spring, while the spaces between the outer portions of the wheel felloe are a sufficient distance apart to act as a guide for the four solid metal spokes which are spaced 90 degrees apart and which radiate from the outer periphery of the hub member. Twelve springs are used, these being mounted in sets of three, each set occupying the space between the two spokes.

The resilient members are attached in such a manner that they are subjected to alternate compression and tension loads. Those at the top of the wheel are under tension, while those at the lower side are under compression. If they should fail in service the work of replacement would entail a degree of mechanical skill not usually possessed by the average motorist. Many inventors have given this problem considerable attention, but it is safe to say that the rubber tire in either of its forms is absolutely necessary to successful motor-vehicle operation, and that

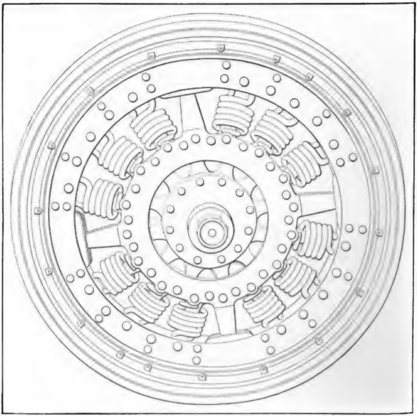


Fig. 259.—Resilient Steel Wheel Having Coil Springs Separating Hub and Rim Members.

there is but little future for resilient wheels depending on springs or other metal resilient members to cushion the shocks met with when traveling over ordinary highways.

Advantages of Detachable Wheels.—Detachable wheels may be either of the metal wheel pattern or of the wood artillery construction. In all forms of detachable wheels two hubs are necessary: an inner member, which is in permanent assembly with the axle, and a removable outer member to which the spokes and rims are attached. In the Rudge-Whitworth construction, shown at Fig. 258, the steel shell to which the spokes are laced is readily removable from the inner member or hub casting proper. The object of this construction is to permit the motorist to carry a spare wheel with a fully inflated tire, so that in event of puncture or blowout it is possible to remove the entire detachable wheel assembly affected and replace it with the spare member carrying the fully inflated tire which has been provided for replacement purposes. All detachable wheels are constructed so that they may be readily removed from the inner hub member, and the entire wheel assembly may be replaced much easier and quicker than replacing the ordinary form of tire. They are especially advantageous when pneumatic tires are used on motor trucks. Wire wheels have no advantages that are not shared by detachable metal disc wheels.

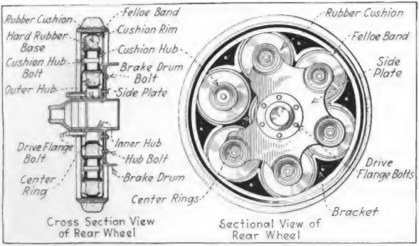

Rubber Cushion
Felloe Band
Hard Rubber Base
Cushion Rim
Cushion Hub
Cushion Hub Bolt
Brake Drum Bolt
Outer Hub
Side Plate
Drive Flange Bolt
Inner Hub
Hub Bolt
Center Ring
Brake Drum
Center Rings
Cross Section View of Rear Wheel
Rubber Cushion
Felloe Band
Side Plate
Drive Flange Bolts
Bracket
Sectional View of Rear Wheel

Fig. 260A.—The Jaxon Wheel for Motor Trucks Uses Rubber Cushions to Carry the Load.

Jaxon Full Floating Wheel.—On trucks equipped with Jaxon wheels, a new development shown at Fig. 260A, the axle is "floated." Rubber cushions which encircle the hub absorb all of the shocks. The cushions give to the wheel the necessary resiliency to overcome all radial, torque and side-thrust shocks—more than doubling the life of tires and increasing the durability of the truck as a whole, as well as increasing the gasoline mileage. The cushions are held firmly in cushion rims—no moving parts to cause friction or wear.

The steel "felloe band" is made to S. A. E. dimensions, so that any standard make of solid rubber tire may be used. To the inside of this band are riveted six equally spaced malleable iron "brackets," between which are mounted six steel "cushion-rims." These rims are tangent to each other, and to the steel "center ring." All of these parts are assembled within the steel felloe band and held firmly in place by contraction of the steel felloe band. The combination forms a light, strong, rigid steel framework that cannot wear, rattle, or buckle in any direction.

The "cushion rims" securely retain a soft, selected grade "rubber cushion," vulcanized to a "hard rubber base" on the outside of a small malleable iron "cushion hub." It will be seen that on each side of the wheel is a steel "side plate" having six integral arms. The extremities of these arms fit into the hollows in the ends of the cushion hubs, and are securely clamped in place by six "cushion hub bolts."

Note that the cup-shaped joint between the side plate arms and the cushion hubs relieves the bolts from all shearing strain, and eliminates any possibility of wear or rattle. The central portions of the two side plates are securely fastened to a cylindrical "outer hub" which fits over the "inner hub" originally furnished on the truck. This construction ties the entire driving portion of the wheel together, and it enables each side plate to take its share of the driving strain.

Cushion wheels are made in many different forms, but in all of these the endeavor seems to be to resist wear due to the abrading effect of the road by using an outer tire of some material that may be lacking in resiliency but which will have the necessary strength and wearing qualities to give a satisfactory mileage. The cushion elements are usually of a very soft rubber that combines great resiliency and flexibility, but which is too soft to resist wear. This rubber cushion is protected by various means, some forms of wheels using solid rims while others have the cushion protected by iron plates. The Martin Cushion Wheel, which is shown at Fig. 260B, is very simple in construction, inasmuch as the cushion is held in place without bolts or nuts. The solid tire and the rim by which it is carried are pressed on to an S.A.E. standard band. A standard band is also pressed on to the wheel felloe. A rubber cushioning strip, which has a series of cushion cups, is interposed between the inner and outer bands. The assembly is held together by rings of T section on both sides of the wheel, which are pressed into place by a powerful hudraulic press, so that all parts of the wheel are held together without the use of the ordinary forms of fastenings. The general construction can be clearly ascertained by reference to the illustration.

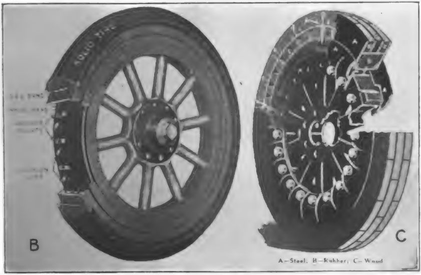
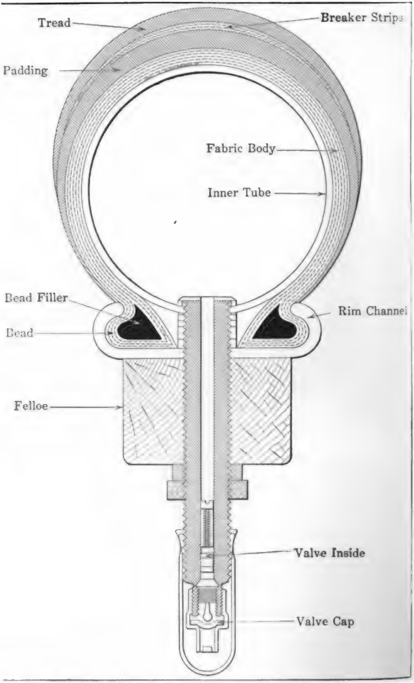


Fig. 260B.—Martin Cushion Wheel. The Universal Truck Wheel is Shown at C.

The Universal Truck Wheel, which is shown at C, Fig. 260B, is a composite structure of steel, rubber and wood. A special wheel, carrying a sectional wood block tire, is supported by a rubber cushion, B, which encircles the main wheel. The tire-carrying member is held by substantial side plates, which are bolted to the wheel felloe. The wheel has a steel casing having whole spokes which are easily renewable, but they have long life,


Tread
Breaker Strips
Padding
Fabric Body
Inner Tube
Bead Filler
Rim Channel
Bead
Felloe
Valve Inside
Valve Cap

g. 261.—Sectional View Outlining Construction of Pneumatic Automobile Tire Fitted to Simple Clincher Rim. This Type of Rim Is Used Only on Light Delivery Automobiles of Ford Manufacture.

which makes frequent renewal unnecessary. The pockets in which the wood blocks set have steel walls, so that the road wear is really taken by a combination wood and steel tread. It is claimed that the wheel has easy riding qualities and that the tread cannot be injured by oils, acids, salts or other chemicals that may affect rubber tires. The rubber cushion is fully protected by the side plates and cannot be reached by any of the agents which ordinarily result in deterioration of rubber tires when used on special duty trucks.

Forms of Automobile Tires.—The wheels of automobiles, with but few exceptions, are provided with rubber tires. The simplest is a solid band of rubber composition; next in order we have the various forms of cushion tires, in which the band of rubber is perforated with a number of small holes or provided with a series of openings designed to provide greater resiliency and make the tire more yielding than the solid-rubber form. Solid tires are invariably adapted to industrial conveyances of large capacity at the present time.

The most common form of tire, and that generally used on automobiles, is composed of a hollow rubber tube of circular section filled with air and protected from wear by means of an outer shoe or casing. The use of air under compression provides a very resilient medium for supporting the vehicle, and of the various forms of rubber tires the pneumatic form is the one that is the most desirable. The development of the modern automobile may be attributed largely to the advances made in pneumatic-tire construction, as these members made it possible to drive automobiles at high speed over rough road surfaces without stressing the mechanism unduly or causing discomfort of the passengers. While solid-rubber tires and members of the cushion form have a certain degree of elasticity, they do not ride as easy as pneumatic tires, because rubber tires cannot be compressed, but only distorted. Solid-rubber and cushion tires are suitable where vehicle speeds are low, but are very unsatisfactory for automobiles of any type traveling at speeds over fifteen miles per hour on anything but the best roads.

Construction of Pneumatic Tires Defined.—The pneumatic tire of the present day is invariably of the double-tube type and is composed of two members, the inner tube and the shoe or carcass. The inner member is utilized to retain the air and is made of a very elastic composition rubber, about an eighth of an inch thick for cars of average weight. While this tube is very elastic and is airtight, it would not be strong enough or have adequate resistance to be run directly in contact with the road surface; therefore, it is necessary to protect it by a shoe composed of layers of fabric and rubber composition. The shoe member is provided with beads on its inner periphery designed to interlock with the rim channel.

The main portion of the fabric outer casing is composed of five or more layers of a Sea Island cotton fabric "frictioned" with high-grade rubber composition. This is forced into the mesh of the cloth by machinery so the fabric will be practically waterproof and will join intimately with the other plies by a process of vulcanization when the shoe is cured. Outside of the fabric body a layer of very resilient rubber, approximately of crescent form, known as the padding, is provided to give a certain degree of elasticity to the shoe. Between this member and the thread a number of pieces of heavy fabric called "breaker strips" are interposed to offer a certain degree of resistance to any sharp object that might penetrate the tread and go through the padding and into the fabric body if the breaker strips were not interposed to deflect the puncturing object to one side. The construction of a fabric tire intended for application to a clincher rim is shown at Fig. 261.

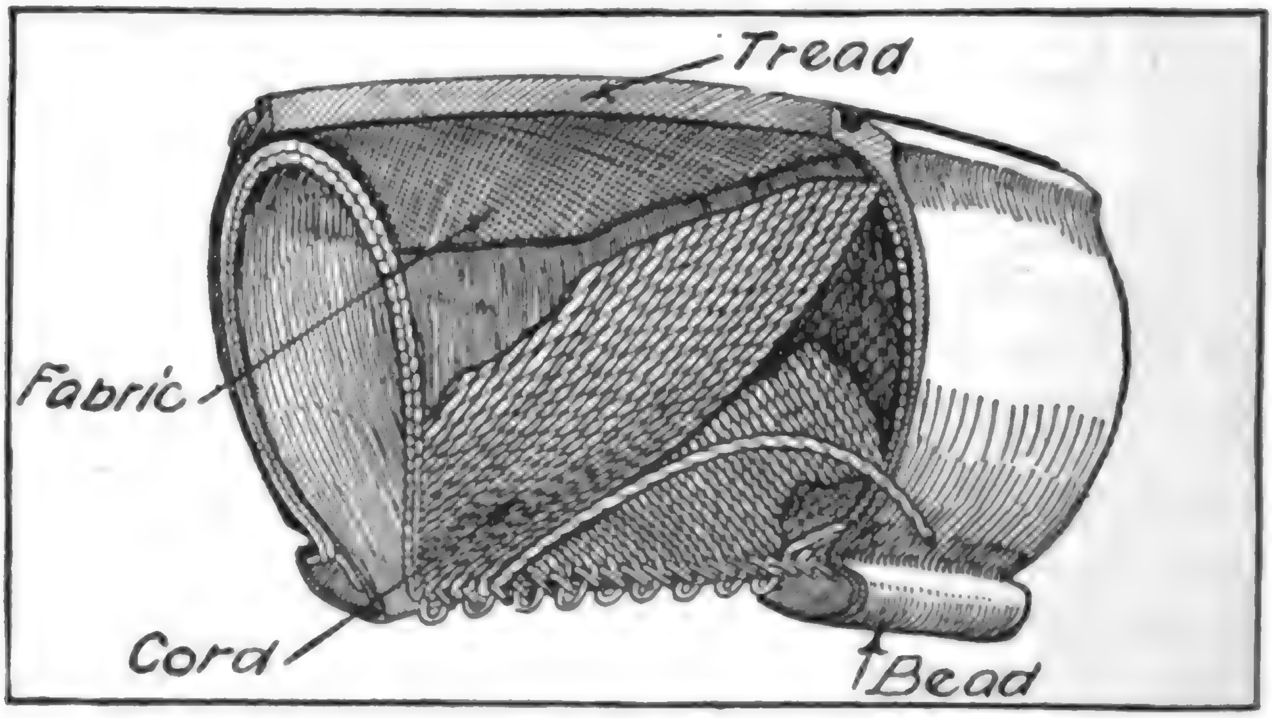


Fig. 262.—Part Sectional View of Tire, Showing Practical Cord Construction.

The tread is the part of the tire that is subjected to the greatest stress, as it must resist the abrading influence of the road and, when the tire is used on the rear wheels, the wearing effect of the friction produced by the tractive effort which exists at the point of contact between the driving member and the ground. The tread is of very tough rubber composition and differs from the material used as padding or for the inner tube in that it does not possess a very great degree of elasticity. This quality is sacrificed for that of greater strength and resistance to wear, which is more essential at this point.

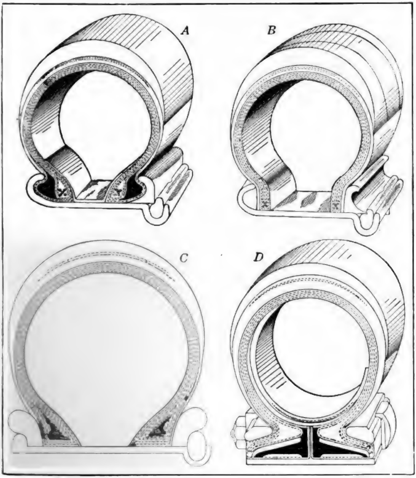


Fig. 263.—Forms of Quick Detachable Rims which Permit Easy Removal of Deflated Pneumatic Tires.

The air is introduced into the tire through a simple form of automatic valve which is securely attached to the inner tube.

As the inner tube becomes distended by the air pumped into it, it forces the beads of the tire outward and clinches the shoe so firmly in the rim channel that it will be impossible to dislodge it without the use of special tire irons, and then only when the air pressure is relieved from the inner tube. The valve is held against its seat by a tension spring and will only open when the valve stem is depressed by the hand or from the pressure of the air forced against it when it is desired to inflate the tire. While the air pressure from the pump will be sufficient to force the valve from its seat, the air pressure from the inside of the tire only serves to hold it more firmly in place.

The general design of practically all fabric outer casings is the same, though there are minor differences of structural detail. For example, some makers will use finer fabric and more layers than others, and each manufacturer has his own specific formulæ for compounding rubber to the best advantage. Some tires are made with a straight side at the lower end instead of the clincher bead, whereas others have been made to be secured to the rim by means of bolts. There are also differences in thickness of the tread and of the padding and breaker strips. Some makers build their tires by what is known as the molded process, while others favor the wrapped tread construction. In the first mentioned method, after the various layers of material of which the tire is composed are assembled together on the core, the assembled tire is clamped tightly in a mold and vulcanized. In the wrapped tread construction, instead of curing the rubber in a mold, the finished tire assembly is wound tightly with narrow strips of webbing to hold the parts together while the curing process takes place. The various members of which the tires are composed are vulcanized by being heated with steam, and sulphur is included in the rubber compounds in proper quantities to permit them to become firmly welded to the friction fabric layers between which they are placed.

The Cord Tire.—A method of tire construction that is becoming popular because of its easy riding qualities and which is a better form for trucks than the fabric tire is shown at Fig. 262. Instead of layers of fabric, the main portion of the carcass or casing is composed of cords which are passed around small wires at the base of the tire and which are wound very tightly in order to secure intimate contact between the various layers of cord. Sheet rubber is placed down between the cord layers and fabric breaker strips are placed between the tread and the cord body in the usual manner. When the tire is vulcanized the spaces between the layers of cord become filled with the rubber, and the whole mass is firmly bound together. The wires project into the bead portion of the tire and are vulcanized firmly in place. Owing to the construction, a cord tire cannot be as easily repaired as the fabric type, because it requires a very expert knowledge of cord tire construction to replace injured portions due to a blowout. Tires of this construction are much more resilient and are capable of giving considerably more mileage than the stiffer form comprised entirely of fabric.

Rim Forms.—Pneumatic tires are not always of the clincher form. Various other constructions have been devised, some to facilitate a more ready removal than the clincher construction permits, while others have been designed to make a more secure attachment by some mechanical means. Various forms of quick-detachable rims and the tires adapted for use with them are shown at Fig. 263. In the ordinary clincher tire it is necessary to force the bead over the channel when it is desired to remove the outer casing, and while this can be accomplished with comparative ease on the smaller tires, it is very difficult to remove or apply large clincher tires. In the form shown at A the clincher rim is made in two parts, one of the sections being easily removable when the locking ring is taken out of the groove in which it fits. When the movable section of the rim is taken off the outer casing may be easily removed, as it can be slipped off the fixed portion of the rim just as a belt can be removed from a pulley.

The Dunlop or straight side type of outer casing is depicted at B and C, these also being fitted to quick-detachable rims. In the Dunlop casing retention is by a series of steel wires at the base of the tire which have a certain amount of holding power, which is further augmented by the air pressure inside of the tube. It is claimed for this construction that it is more easily removed than the clincher tire when applied to a one-piece rim, though on the quick-detachable type shown in illustration one form is as easily removed as the other. The rim shown at A and B is the same member, and it will take either clincher or Dunlop type casing. When used for the latter a rubber filler ring is provided to fill the channel of the fixed portion of the rim, while the flat side of the removable portion is brought in contact with the casing walls instead of the channel or hooked side. The form shown at C is made exclusively for use with Dunlop type casings, and cannot be utilized for clinched tires.

At D the Fisk bolted-on casing is shown, but this form is now practically obsolete and will be noticed on only very old model cars. This differs from the other forms in that the clinchers are designed in such a manner that they practically form a foot or base, and when closed together will keep the inner tube away from the rim, which is not done with the other forms of rims. The rim proper consists of a flat band of steel attached to the wheel felloe. Two locking rings are provided, one at either side of the tire, and these are held into proper relation and clamped tightly against the base member of the shoe by means of bolts which pass through the enlarged beads of the casing. This form of attachment is very secure, and the tire is held to the rim positively whether or not it is inflated.

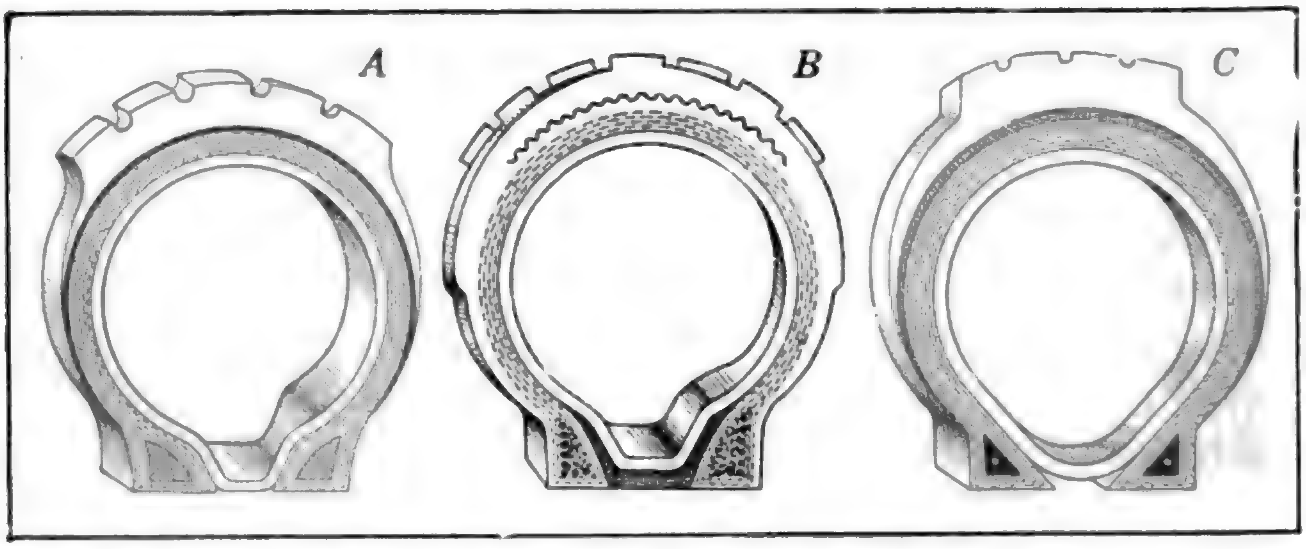


Fig. 264.—Showing Various Raised Treads Used on Pneumatic Tire Casings.

Special Casing Treads.—The casings shown at Fig. 264 are a few of the forms which have been designed to secure greater life of the thread. In that shown at A the tread is raised at five portions and is very thick. In that shown at B the tread is provided with a large number of small rubber studs or projections which are depended on to prevent side slip more than providing any great amount of added wear to the tread. The form shown at C is known as a raised-tread type, and in this the round tread is reinforced with a flat band running around the outer periphery, this providing a greater thickness of tread than will be possible with the round-tread construction.

The construction of inner tubes is practically the same in all standard makes of tires, and these are usually interchangeable. The outer casings differ in some respects, these being merely a matter of detail involving the number of plies of fabric, the thickness of the padding, the arrangement of breaker strips, and the character of the tread. All the tires shown at Fig. 263 have the plain round tread, which is well adapted for use on front wheels. The smooth tread, however, has the disadvantage in that it is liable to slip on muddy roads, and for this reason a

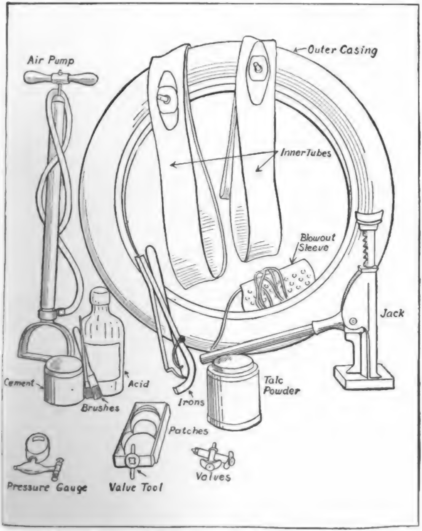

Air Pump
Outer Casing
Inner Tubes
Blowout Sleeve
Jack
Cement
Acid
Brushes
Irons
Talc Powder
Patches
Pressure Gauge
Valve Tool
Valves

Fig. 265.—Spare Parts and Necessary Repair Equipment for Automobiles Using Pneumatic Tires.

number of tread forms have been designed to secure greater adhesion to the road or to reduce wear. A round-tread tire will wear off until the breaker strips are exposed, and the tire should be retreaded as soon as this condition is apparent.

The variety of so-called anti-skid treads is greater than the number of tire manufacturers, as some offer several "sculptured treads" and all have at least some pet form. The most practical tread of this nature, in the writer's opinion, is that having the surface divided into substantial diamonds, as shown at Fig. 267C, because these have sufficient size to resist the road wear well and at the same time present a variety of angular members to resist side slip on wet or soft roads.

Tools and Supplies for Pneumatic Tire Restoration.—It has been previously stated that one of the chief disadvantages of pneumatic tires has been their liability of failure by puncturing the outer casing and penetrating the inner tube and thus providing a means for escape of the compressed air in the inner tube. The life of a pneumatic tire is decidedly uncertain and will depend on many factors outside of those of purely natural wear. There have been cases where outer casings have given satisfactory service for seven or eight thousand miles, but these instances have been the exception rather than the rule. It is the opinion of most motorists who have had practical experience that if an ordinary set of shoes will give a service averaging four thousand miles that they are equal to the demands made upon them and that they are satisfactory. It may be stated that tires will last longer on light trucks than heavy ones, and the service obtained from tires fitted to vehicles driven at low and moderate speeds will be much greater than that obtained from tires fitted to high-speed trucks. There is also a personal element which must be taken into consideration, and that is the way that the car is driven and the care taken of the shoes and inner tubes.

It is necessary, therefore, in all cars using pneumatic tires to carry a certain amount of equipment for handling and repairing these on the road. A typical outfit is shown at Fig. 265, this consisting of a spare outer casing, two extra inner tubes for replacement purposes, a blow-out sleeve, a number of patches, and an acid-cure vulcanizing outfit or small flame outfit for applying them. Tire irons must be provided to remove the casing from the rim; the jack is used to raise the wheel of the vehicle on which the defective tire is installed from the ground and make it possible to remove the tire completely from the wheel. The air pump is needed to inflate the repaired tube or the new member inserted to take its place. The talcum powder is sprinkled between the casing and the tube to prevent chafing or heating, while the spare valves and valve tool will be found useful in

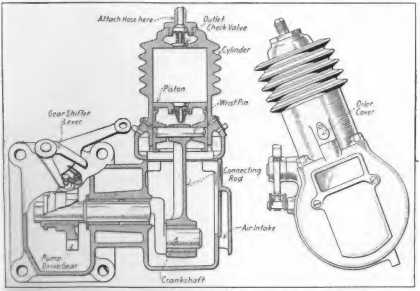


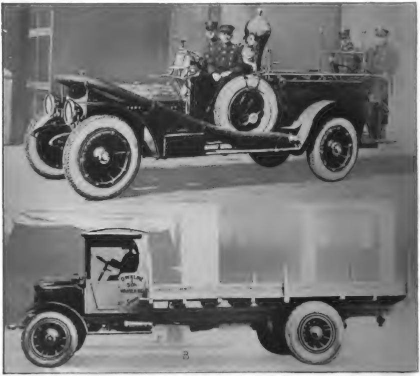
Fig. 266.—Details of Power Operated Air Pump Driven From the Change Speed Gearing to Which It Is Attached.

event of damage to that important component of the inner tube. As it is desirable to inflate the tires to a certain definite pressure, a small gauge which will show the amount of compression in the tire is useful.

When the tires of the pneumatic form are applied to a motor truck, they are of very large size, and blowing them up with a hand-operated pump would be very arduous work. For that reason, a power-driven air pump, as shown at Fig. 266, is usually fitted to the truck chassis in some position where it can be driven off of the engine or the side of the change-speed gearing, this furnishing all the air necessary without any exertion on the operator's part.

Pneumatic Motor Truck Tires.—Data compiled by the Goodyear Tire and Rubber Co., Akron, Ohio, who were pioneers in the application of air-filled tires on motor trucks, show that these have advantages in certain applications that are of marked value.

In a recent article on this subject they give facts supported by reports of users which indicate that they have been used successfully on many kinds of trucks. Never in the history of the motor truck industry has any proposition presented itself which had greater possibilities than pneumatic cord truck tires seem to have. Many years have been spent in the development of this tire, with the result that today the product is fully beyond the experimental stage and meeting with success in the truck tire field. All the advantages of the pneumatic cord tire for trucks center around two fundamental qualities—cushioning and traction. Cushioning—Reduction of truck repairs and truck depreciation. Reduction in load damage. Traction—Greater daily radius of operation. Savings in fuel and oil.



Figs. 267A and B.—Large Pneumatic Tires Fitted to Trucks, Fire Apparatus at A and Contractor's Equipment at B.

Compressed air enclosed in tubes protected by the casings of the cord tire construction provides the best cushion ever discovered for transportation purposes. It is the cushioning that evens truck action, that smooths its travel—not merely over bumpy going, but over the heavier rolling, rugged and stony roads. The result is a reduction of repair bills, less time spent in costly lay-ups, less depreciation of truck, minimum breakage of fragile goods. The cushioning of the pneumatics shows saving: (a) In trucks. (b) In hauling time. (c) In loads. (d) In roads.

Reports from those who haul fragile merchandise, such as glassware and the like, The Westinghouse Glass Co., furnishes a good example of the cushioning qualities of these pneumatics. The Chicago branch of this company conducted a test, covering a long period, in which it was determined the percentage of breakage in Mazda lamps transported by three different methods. Average breakage, by freight or express, 11 per cent; by truck on solids, 15 per cent; on pneumatic cords, 4 per cent.

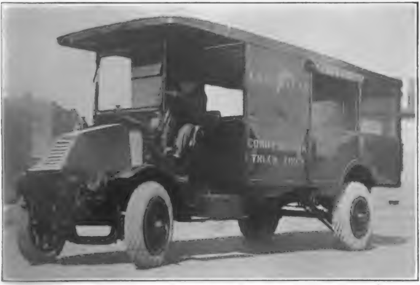


Fig. 267C.—Pneumatic Truck Tires Increase Truck Speed and Lessen Depreciation of Mechanism.

Careful observations by highway engineers have shown that solid-tired trucks tend to increase the cost of highway upkeep, even on hard surface highways. On the other hand, trucks on pneumatic cord tires have no more effect than the lightest passenger tires. Also, the vibration of solid-tired trucks produced greater strain on bridges—trucks on pneumatics roll smoothly across, causing least jarring and shaking. As definite knowledge on this subject is accumulated, it is expected that the road effect of truck tires will develop into an important factor in determining the type of tires on most trucks used on our highways.

The pneumatic cord tire has a broad wearing surface, plus a positive grip on ground surface. The non-skid feature of the pneumatic cord tire enables uninterrupted travel through sand, snow, mud, or on ice. Such conditions cause hard edge solids to slip and stall. Consequently, the pneumatic-tired truck has greater earning power. Trucks on pneumatic cord tires can maintain their usual rate of speed over rough sections on which solid-tired trucks must slow down. In addition it has been noted that pneumatic-tired trucks cover more distance and carry more loads on good roads in a day. They enable the truck-owners to cut down labor cost and unit mile cost while increasing the territory and number of customers served.

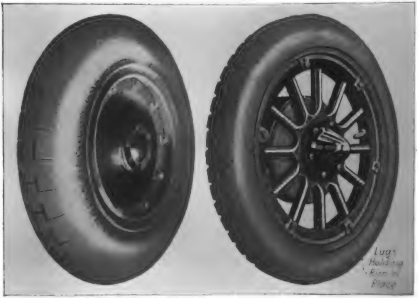


Fig. 268.—Large Size Pneumatic Truck Tire Mounted on Demountable Rim Shown at Left. Wheel of Reo Speed Wagon Shown at Right.

In increasing the daily radius of operation pneumatic tire cords enable trucks to maintain their usual rate of speed most of the time. They do increase the minimum speed of trucks, and the average speed of units, formerly on solids, usually is considerably higher as a result. Cushioning and traction save that slowing down over bad stretches that is necessary on solid tires. Pneumatic-tired trucks are most active in traffic and quicker at the get-away.

The reduction of vibration saves the truck mechanism and depreciation is reduced a noticeable degree. Some truck-owners report less repairs after running on pneumatics a year than were necessary on solid-tire equipped trucks in a few months.

Directions for Application of Pneumatic Truck Tires.—First—With a small pneumatic tire it is customary first to insert the valve of the tube through the valve stem hole of the rim, and then to pry and pound the tire over the rim. This method cannot be followed with a pneumatic truck tire because of the stiffness of the beads and the width of the rim. Instead, you first lay the tire squarely on the rim with the valve-stem over the valve-stem hole of the rim.

Second—Allow the tire to drop down evenly until the valve-stem is reached, then press the valve-stem down sideways and toward the end of the flap.

Third—Hold the valve-stem in this position with a thin bar, taking care when the tire slips down the rest of the way that the valve-stem does not catch in the locking groove. During this operation a valve-cap should be put on the valve-stem to protect the threads. New types of rims are being made which have valve-stem slots to facilitate application of tire.

Fourth—When the tire is completely on the rim it can be readily turned from one side to the other until the valve-stem appears at the valve-stem hole and can be pulled through. Next the rim nut should be screwed on the valve-stem until the valve is fastened securely in the center of the valve-stem hole.

Fifth—You are now ready to put on the second side ring, which will slip over the rim easily if too much air has not been put in the inner tube. By means of a large tire iron, force the side ring down into place all the way round the tire. You should now be able to insert the hooked end of the locking ring into the locking ring hole. Continue to press the side ring down and at the same time fit the locking ring into the channel.

Sixth—Care should be taken not to spring the locking ring during this operation. When mounting the 42 x 9 and 44 x 10 size it will be necessary to pound this ring somewhat before entering the channel. Be certain that the locking ring has sprung into place around its entire circumference.

Seventh—The tire is now ready for inflation. Remember—UNDERINFLATION RUINS TIRES—so avoid this risk. To make sure that you are using the proper inflation pressure for the load the tire is to carry, consult the inflation chart below, and use pressure gauge when inflating the tire. Never run a tire flat or very much deflated—it means ruin. Also guard carefully against overloading.

GOODYEAR CORD TIRES FOR TRUCKS

Proper Loads and Inflation Pressures

Inflation Pressure (lbs.)	TIRE SECTION DIAMETER							
	4½-in.	5-in.	6-in.	7-in.	8-in.	9-in.	10-in.	12-in.
80	1350	1570						
90		1660	2000					
100				2700				
110					3650			
120						4650		
130							5800	
140								8500

Note that the ideal tire loads under average conditions are shown. Do not inflate harder than the specified figures.

Machine for Handling Large Tires.—The Vance Engineering Company, 227-233 West Erie Street, Chicago, announces through the "Power Wagon" a tire-setting machine, which it claims is one of the biggest boons to the manufacturers and users of large pneumatic tires yet produced. Realizing that the use of large pneumatic tires on heavy motor trucks is practical and knowing the difficulty encountered in placing a tire of large dimension on a rim, likewise the removal of such a tire, this company began experimental work several months ago on a device to reduce this process to a minimum, and after numberless tests on all sizes of tires and types of rims, finally produced the machine as shown in the accompanying cut, Fig. 269. Probably the biggest factor in connection with the machine is that of the speed with which tires are placed on rims or removed therefrom. Tests on various makes of tires show the following results: 48 by 10-inch, one tire q. d. rim, 2 minutes; 38 by 7-inch, one tire q. d. rim, 1⅔ minutes; 35 by 5-inch, one tire s. s. split, 2 minutes; 34 by 4½-inch, one tire clincher, q. d., 1½ minutes.

Removals are made in like time. It is quite common under the old method to have two men spend thirty minutes to an hour in hard, nerve-racking labor placing one of these tires on the rim, even when working under ideal conditions. The care which must be exercised when doing the work by hand for fear of damaging the bead of the rim naturally means slow work.

MAXIMUM LOADS IN POUNDS FOR SINGLE SOLID AND PNEUMATIC CORD TIRES FOR MOTOR TRUCKS AS RECOMMENDED BY THE PRINCIPAL TIRE MANUFACTURERS

(From *Power Wagon*)

(Figures in bold-faced type show the loads most frequently recommended.)

Inflation Pressure in Pounds	Size of Tires in Inches											
	3	3½	4	4½	5	6	7	8	9	10	12	14
Solid	**1,000**	1,000 **1,300**	1,500 **1,700**		2,000 **2,500** 2,600 2,650	**3,300** 3,500	**4,200** 4,500	5,000 **5,200** 5,600		6,750 **7,000** 7,500	8,500 **8,800** 9,500	**10,600** 11,500
60			**850**	1,020	1,400							
65				1,080	1,500							
70				1,140	1,550	1,800						
75				**1,200**	1,600							
80					**1,700**	1,800 2,000	2,500	3,175				
90						2,000 2,200	2,450 2,700 2,775	3,450		4,000		
100						2,000 3,000	2,700 **3,000** 3,725	3,350 4,350		5,000		
110						2,400	2,950 4,000	3,650 **4,000** 4,675	4,300	5,300		
120							3,200	3,950 5,000	4,650 **5,000**	5,350 5,650		
130								4,250	5,000	5,800 **6,000**		
140									5,350	6,250		
150										6,700		

The saving in time apparently is great. The positive and uniform operation and pressure as applied assures a lesser wear on the bead of the tire, which is the all-important spot that has to be contended with. The fact that the machine is operated by foot power, eliminating extras in the way of motor or other driving power, and takes up a space of only sixteen square feet, makes it an easy and inexpensive installation. The machine is well constructed along simple lines, all parts being machined, hydraulic pressure being the motive power, and all parts are easily accessible. Various shoes are furnished as a part of the standard equipment, enabling one to handle rims of all types. The change from one set of shoes to another can be made in less than one minute.

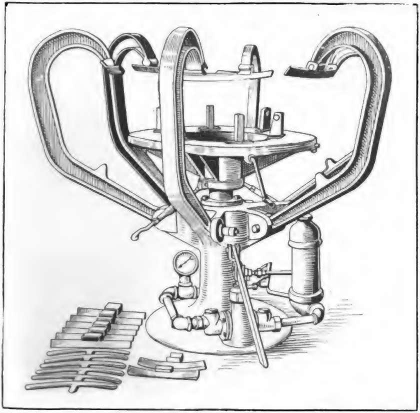


Fig. 269.—Special Machine for Mounting and Demounting Large Pneumatic Tires.

Features of Cushion Tires.—Some classes of vehicles that are not designed to run at high rates of speed, and which are not intended to carry heavy loads, are filled with cushion tires. While these do not have the resiliency of the pneumatic form, they have much greater flexibility than solid-rubber tires. For this reason they are sometimes used on the electrically propelled light delivery or pleasure vehicles and sometimes on the lightweight commercial cars of the gasoline type. Some of the popular forms of cushion tires are shown at Fig. 270. At A the tire tread, which is of the dual form, is molded in such a manner that a series of shallow grooves are formed around the tire. These incline from the outside toward the center and are depended on to give improved traction as well as to make the tire more resilient. The base of the tire is pierced with a large number of holes which extend clear through from side to side, so the outer tread or load-carrying portion is supported on a series of rubber bridges which are adapted to bend and provide a certain degree of flexibility.

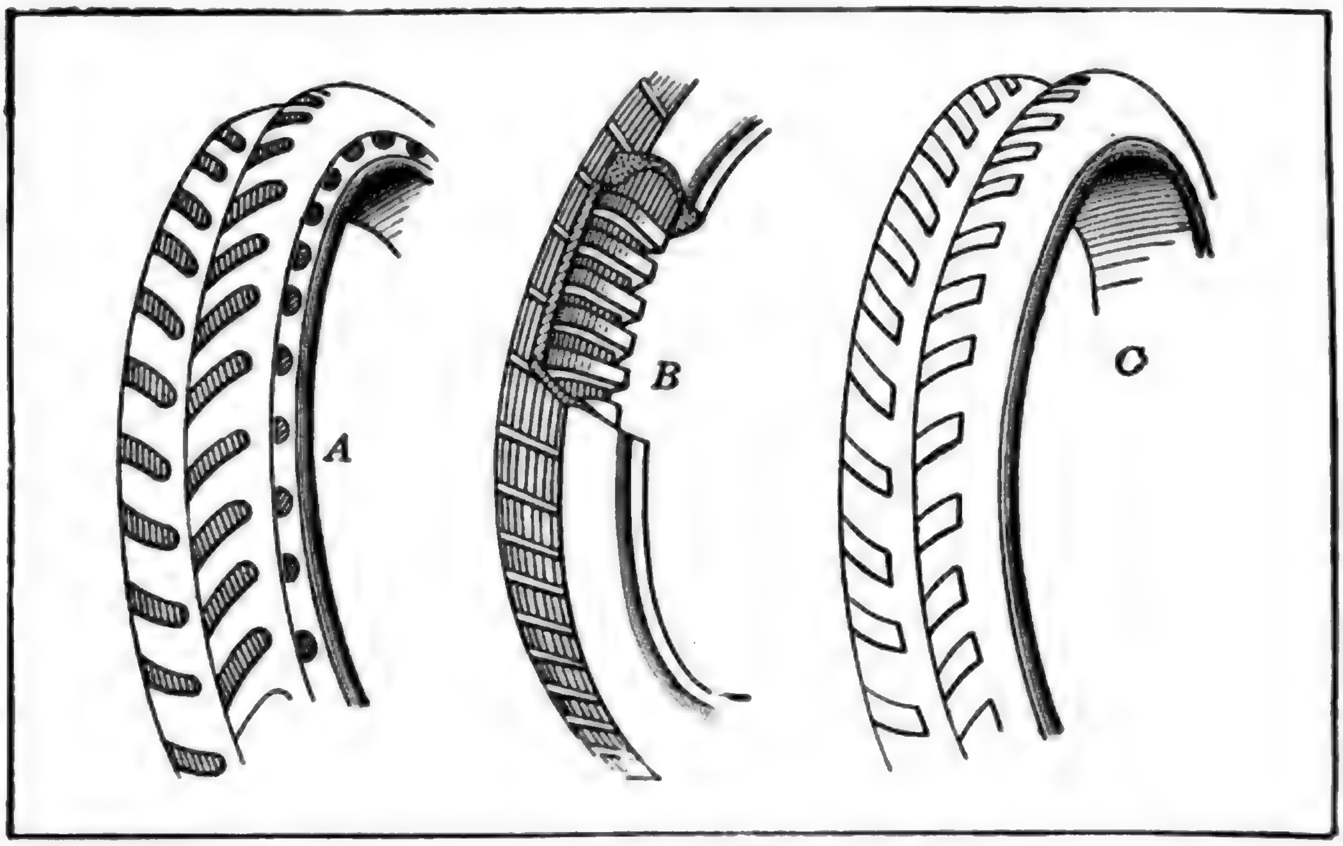
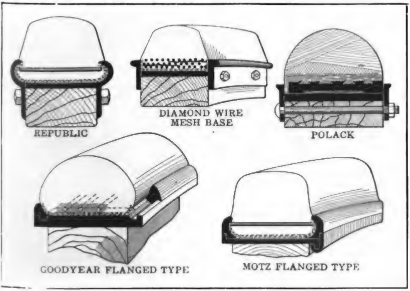


Fig. 270.—Cushion Tires which Provide More Resiliency than Solid Rubber Tires, but which are Not Equal to the Air-filled Forms.

The cushion tire shown at B is similar in form to the conventional clincher casing, and is designed to be used on clincher rims of the pattern commonly supplied with pneumatic tires. The flexible feature of this tire is obtained by using a number of rubber load-supporting partitions to join the walls of the tire, and at the same time they are separated from each other by an ir space of sufficient size so the tire will distort more easily han the conventional solid-rubber pattern. The cushion tire hown at C depends upon the form of tread to provide resiliency, nd it would not be as flexible as either of the two forms previusly considered.

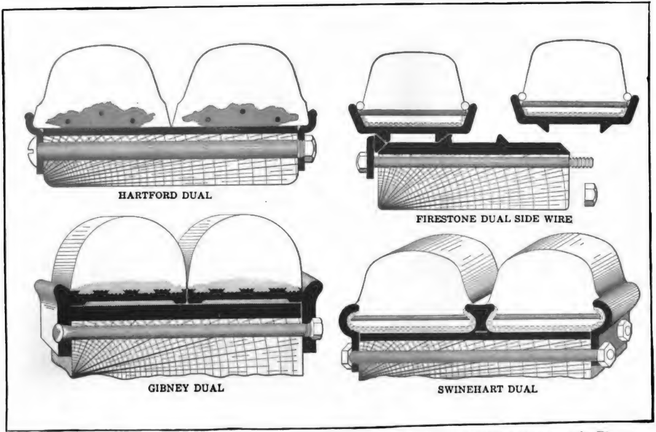
One objection to either solid or cushion tires is that a deep ut or stone bruise will seriously weaken the entire structure, vhereas only a limited portion is really unfit for use. Then, gain, sometimes, when brakes are locked too suddenly, a por-



ig. 270A.—Outlining Construction and Methods of Fastening Solid Rubber Tires to Wheels.

on of the tire may be worn more than the other parts, but the ntire efficiency of the tire will be affected and the strength will epend upon that of the weakest portion.

Forms of Solid-Rubber Tires.—On very heavy commercial ehicles it is not considered advisable to use pneumatic tires, ecause these would have to be of very large size to carry the ads imposed by the usual heavy truck chassis and loaded body. s the speeds of these vehicles are not very high, solid-rubber res may be employed to advantage. These are molded from ecial rubber compositions in one continuous ring, and they are sually provided with some form of metal reinforcement at the ttom which insures that they will clamp tightly against the


HARTFORD DUAL
FIRESTONE DUAL SIDE WIRE
GIBNEY DUAL
SWINEHART DUAL

Many Types and Methods of Holding Members in Place rim or the felloe band. Various forms of quick-detachable rims have been evolved to hold these members in place, and the metal reinforcements at the bottom vary from simple transverse wires to continuous bands of steel molded integral at the base of the rubber rings.

A number of solid tires and methods of attachment are clearly shown at Fig. 270A. Single tires of this form are used on the front wheels of practically all trucks, though the rear members are generally supplied with dual tires, which have greater carrying capacity and which also lessen the dangers of side slip on wet pavements. When twin tires are used it is desirable that they be installed in such a way that they can be readily removed from the wheel for replacement in event of wear, and it is also thought necessary to provide means of attachment of such nature that they can be removed independently, if desired. Various dual tire forms and the method of holding them in place are shown at Fig. 271.

Solid-rubber tires applied to trucks are sometimes of such form that special machinery is needed to install them, and the work can only be done at depots where this form of machinery formed part of the equipment. When accident to the tire or natural wear made it necessary to replace the worn member with a new one, the wheel had to be removed from the truck and sent to the tire company's station to be fitted up with tires. This meant a loss of time of some magnitude, which has been entirely overcome by the new demountable construction. Spare tires may be carried in stock and may be used to replace the damaged members without the use of special applying machinery in most instances and without necessitating the removal of the wheel.

Installing Solid Tires.—At the present time the solid tires used on trucks are generally a pressed-on type, because these have been found to give the best satisfaction as compared with the demountable types, and few owners have equipment for removing or installing them on wheels.

To meet these requirements the Wellman-Seaver-Morgan Co., Cleveland, O., has recently developed a hydraulic press for mounting and demounting solid tires. The illustration at Fig. 272 shows one of these presses. The press consists of an upper and lower platen held in a frame of I beams. The lower platen is moved by a ram working in a cylinder and actuated by a hydraulic pump. The press is equipped with pressure gaug relief valve and control valve, and can be either driven from line shaft or by a separate motor.

To mount a tire, the ram is lowered, the wheel is placed on th lower platen and the tire in position above it. Power is the applied, either by throwing the belt on the tight pulley or star ing the motor. The control valve is then closed and the tire pressed onto the wheel. To demount a tire, a ring is placed o the lower platen just large enough to clear the wheel which placed upon it. A second ring or a set of blocks is placed o the circumference of the wheel, the control valve is then close and the tire pressed down off the wheel rim.

The presses are designed to mount and demount all sizes u to the largest solid tire built—42 by 14 inches. These press are giving the best of satisfaction, and it is claimed that a fro wheel has been removed, the old tire pressed off, a new tir installed and the wheel remounted in seven minutes. The sam work has been done with rear wheels and dual tires in 45 minute

SOLID TIRE AND WOOD WHEEL SIZES

Capacity of vehicle in Tons	Position and kind of Tire	Size of Tire in Inches	Spokes		Diameter Flange Inches	Weight Wheel i Pound
			Number	Width in Inches		
1	Front, single	36 x 4	12	2	9	4
1	Rear, single	36 x 6	14	2¼	10	9
2	Front, single	36 x 4	12	2	9½	4
2	Rear, dual	36 x 4	14	2½	10½	13
3	Front, single	36 x 5	14	2½	10	7
3	Rear, dual	36 x 5	14	3	12	16
4	Front, single	36 x 5	14	2½	11½	7
4	Rear, dual	40 x 5	14	3½	13	20
5—5½	Front, single	36 x 6	14	3	12	10
5—5½	Rear, dual	40 x 6	14	4	13½	24
7—7½	Front, single	36 x 7	14	3	12	11
7—7½	Rear, dual	40 x 7	14	4	14	27

Removing the wheels from the axles and spindles is anoth work that can be expedited with the simplest equipment, yet tw men are often needed to do this and the labor is heavy. Whe the wheel has been jacked a short piece of hard wood board c plank and three short pieces of iron pipe or rod should be shove under it, the pipe or rod at right angles to the axle. The boar should be two inches thick, 18 inches long and six inches wid and the pipe or rod may be from six inches to a foot long, as shown at Fig. 273.

With the wheel resting on the board it may be drawn off the axle, and then run off the board and placed wherever wanted. The same equipment will serve on even rough ground by using two pieces of board with the pipe or rod rolls between them, and jacking the wheel higher. When replacing wheels the boards and rolls are used in reverse of the removal. With the boards and rolls, which cost practically nothing, one man can handle a wheel as well as two. Special cranes may be procured for this work from makers of garage appliances.

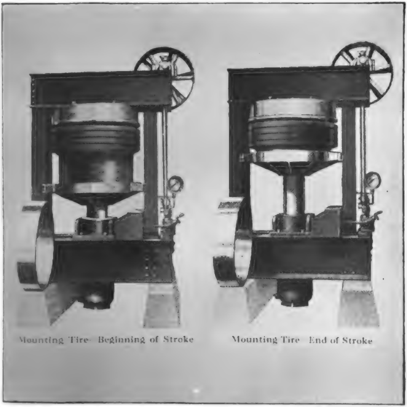

Mounting Tire—Beginning of Stroke
Mounting Tire—End of Stroke

Fig. 272.—Press Used for Installing and Removing Solid Rubber Truck Tires.

Utility of Motor Truck Brakes.—One of the most important of the components of the motor truck controlling system is usually carried with and forms part of the rear construction, this being the braking means which is utilized to bring the truck to a stop when it is desired to arrest forward or backward motion. It will be evident that in a horse-drawn vehicle the animal drawing it can be used as a brake, but that in any form of self-propelling conveyance it is essential that some means of stopping be included in the construction. Even if the clutch was operated in such a way that the motor was disconnected from the driving wheels, the conveyance would continue to move because it had acquired a certain momentum which would increase in value with the weight of the car, the gradient and the speed at which it was driven.

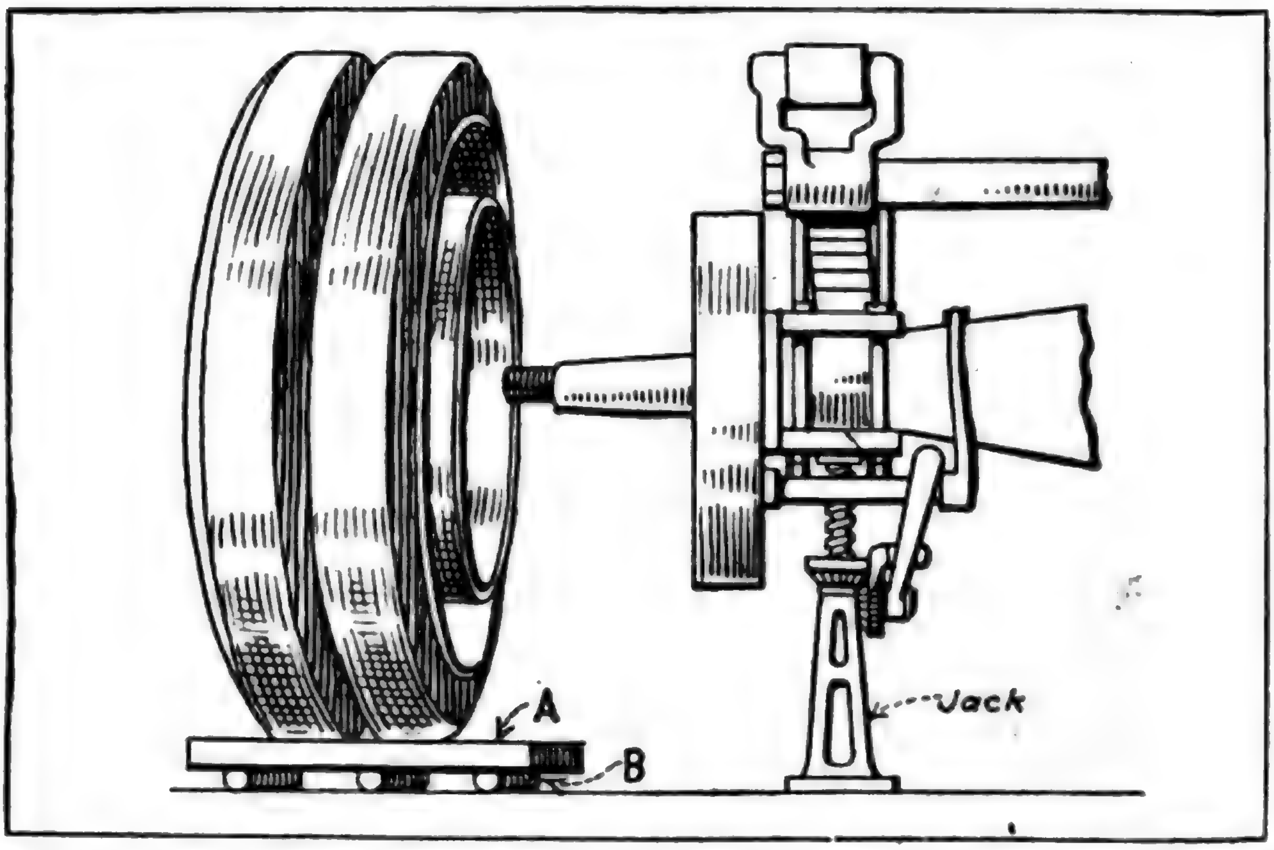


Fig. 273.—Easy Method of Removing Heavy Truck Wheel from Axle.

On some forms of horse-drawn vehicles, particularly those of large capacity, some form of supplemental retarding member must be provided to assist the braking effect of the animal which may not be sufficient to stop the vehicle when descending grades or when operated with some degree of speed on the level.

A simple form of shoe brake, such as used on a horse-drawn conveyance, is shown at Fig. 274. This consists of a brake block of wood or other material carried at the end of a fulcrumed lever which in turn is joined to a pedal by a connecting link. When it is desired to bring the vehicle to a stop, a moderate degree of pressure at the foot pedal will bring the brake block in contact with the tire on the periphery of the wheel and but a very moderate amount of pressure suffices to lock the wheel in a positive manner. This construction could not be very well applied to motor vehicles, because the action of the shoe against the rubber tire would be apt to produce rapid depreciation of these costly elements. For this reason the brakes of automobiles are especially designed so that they will wear instead of producing deterioration of the points to which they are applied.

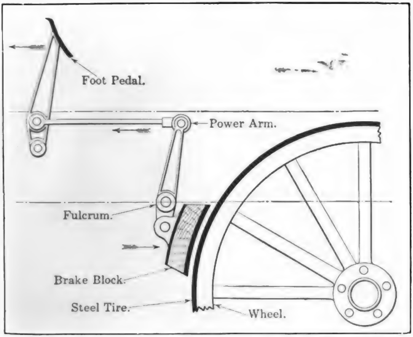


Fig. 274.—Simple Form of Shoe Brake Used on Horse-Drawn Vehicles.

Forms of Motor Car Brakes.—The braking members generally used on motor trucks may be divided into two classes, each of these depending upon the property of frictional adhesion between substances held together by considerable pressure. The usual construction is to attach a drum to some portion of the change-speed-mechanism, to the final drive gear or to the wheels themselves. At the present time most engineers favor applying one of the brakes directly to the driving wheels, and pressed-steel drums are usually fastened to these members, against which the brake acts. The retarding effect may be obtained either by an internal expanding shoe brake or by an external contracting hand brake.

The principal forms are outlined at Fig. 275. One of these consists of an internal expanding band member consisting of an asbestos band which conforms to the curvature of the brake drums. The ends of the band are spread apart and brought into forcible contact with the drum by means of a simple lever and toggle linkage. Another method of expanding the internal band so it will engage the inner surface of the drum is outlined at Fig. 279, A. In this the toggle linkage is replaced by a cam which is rocked by a lever to force the brake shoes apart when it is moved in one direction and permits them to close up and release the drum when it is rocked the other way.

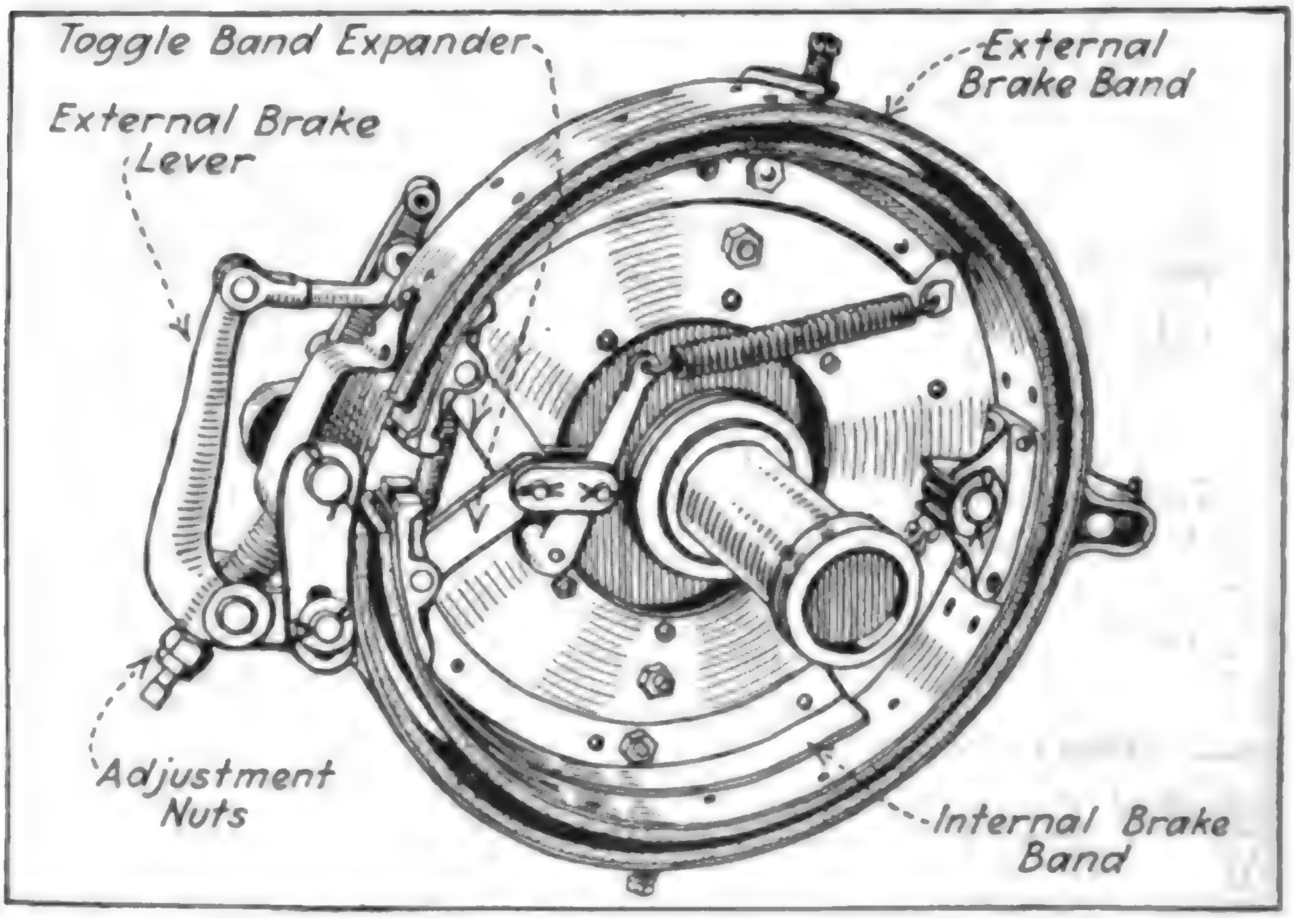


Fig. 275.—Typical Motor Truck Brake Assembly. One of These Sets Is Provided for Each Rear Wheel.

The external brake shown at Fig. 275 consists of a steel band which is lined with some friction material possessing considerable resistance to heat, such as asbestos-wire fabric. The band is attached to lever in such a way that it will be brought into forcible engagement with the external surface of the drum if the end of the lever is moved. Another form of external brake is depicted at Fig. 279, B. This is a very efficient double shoe form, and it has great holding power. The shoes may be adjusted as the friction material wears, and thus the brake may be always kept in perfect adjustment.

At Fig. 277, which shows the axle of I. H. C. trucks, one will notice two internal expanding bands are mounted inside of each brake drum, one pair of these being connected to a pedal and used as a service brake, while the other is attached to a hand lever and is depended upon as an emergency or auxiliary braking member. The cast shoes are hinged at their lower end and are faced with friction material. They are spread by means of cam expanders, and when the shoes are spread apart they engage the inner portion of the brake drums with considerable force.

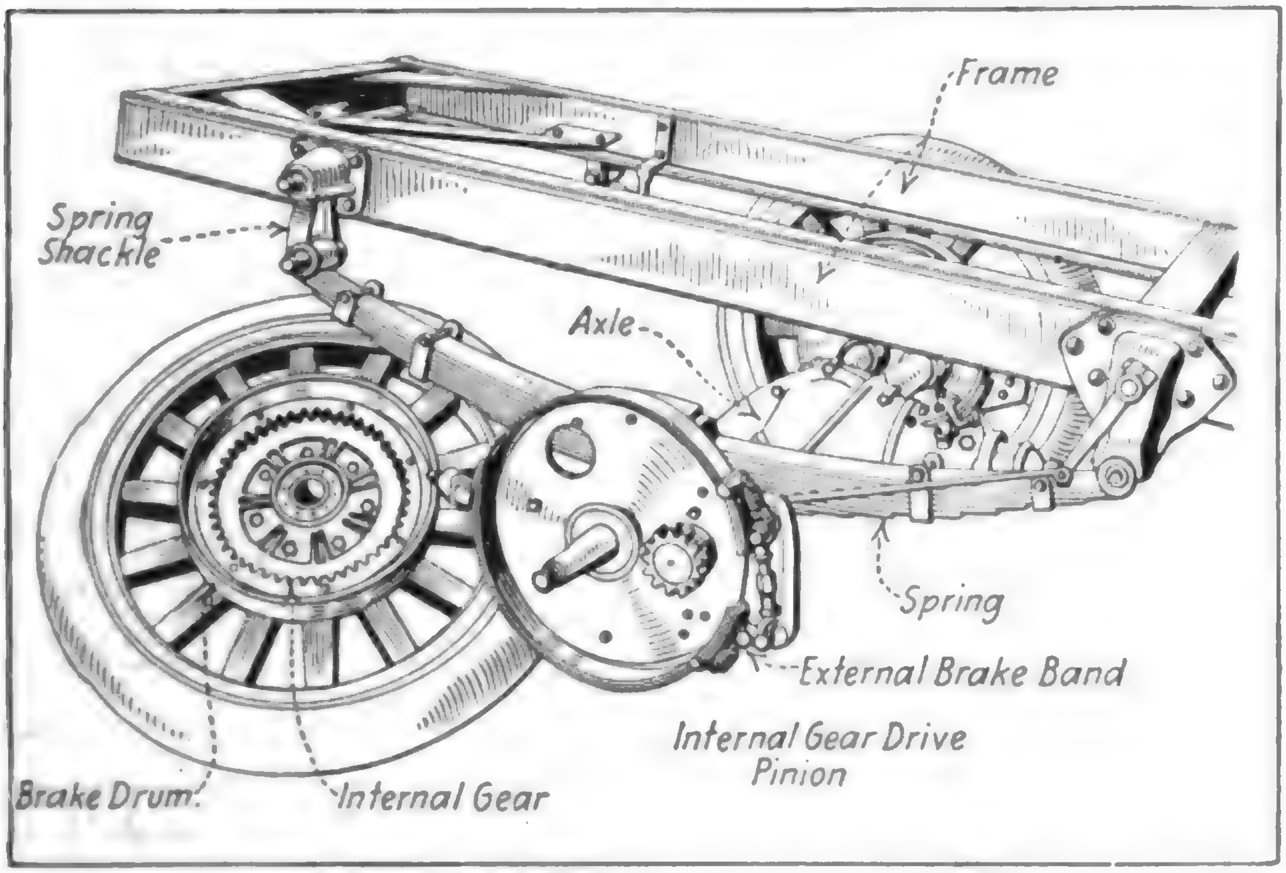


Fig. 276.—External Constricting Band Brake Used on Light Truck.

A combination of internal expanding and external constricting brakes is shown at Fig. 275. This is a very common method of construction and is found on many passenger cars and a number of trucks. The inner brakes are usually depended on for emergency service, while the outer brakes, which may be more easily applied, are used for braking under ordinary conditions. A common brake drum serves both brakes, as the expanding member will engage the inner periphery, while the external band will contract around the outer face of the drum.

The braking members in automobiles have been mounted on both front and rear wheels, on the jackshaft of a double-chain driven car, or on the propeller shaft of a bevel or worm-gear drive arrangement. The propeller shaft brake of Packard trucks is clearly shown at B, Fig. 279, and consists of a pair of lined shoes carried by curved levers which are brought together by cam mechanism. This form is sometimes known as a "caliper" brake.

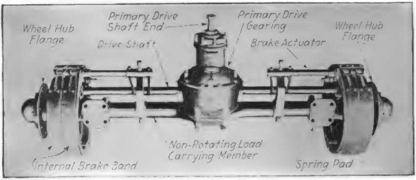

Wheel Hub Flange
Primary Drive Shaft End
Drive Shaft
Primary Drive Gearing
Brake Actuator
Wheel Hub Flange
Non-Rotating Load Carrying Member
Internal Brake Band
Spring Pad

Fig. 277.—Rear Axle of I. H. C. Truck with Wheels Removed to Show Double Internal Band Brakes.

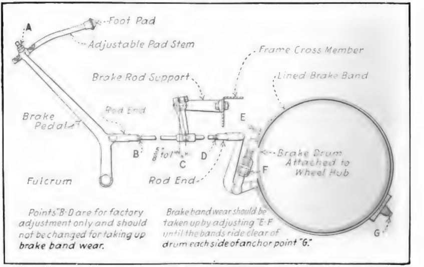

A
Foot Pad
Adjustable Pad Stem
Frame Cross Member
Brake Rod Support
Lined Brake Band
Rod End
Brake Pedal
E
B
5/8 tol
C
D
Brake Drum Attached to Wheel Hub
F
Fulcrum
Rod End
Points "B-D are for factory adjustment only and should not be changed for taking up brake band wear.
Brake band wear should be taken up by adjusting "E-F until the bands ride clear of drum each side of anchor point "G."
G

Fig. 278A.—Showing All Parts of Typical Foot-Actuated External Constricting Band Brake, with Points for Adjustment Outlined.

The usual methods of brake actuation by pedal and hand lever, also the connecting linkage and means of adjustment for both internal and external brakes, are shown at Figs. 278A, and 278B.

Ball and Roller Bearings.—The plain bearings which have received wide application in all forms of machinery are not as popular in automobile construction, because in the self-propelling mechanism it is important that the power generated by the motor should be delivered to the traction members with as little loss as possible. Plain bearings consume considerably more power than do the anti-friction types, and because of this the latter are employed generally throughout the power transmission system and wheels of all types of cars, while they have replaced the plain bearings used on motor crankshafts to some extent as well. Anti-friction bearings are those in which rolling friction is substituted for sliding friction and consume from one-fourth to one-eighth as much power as plain bearing forms of equivalent capacity.

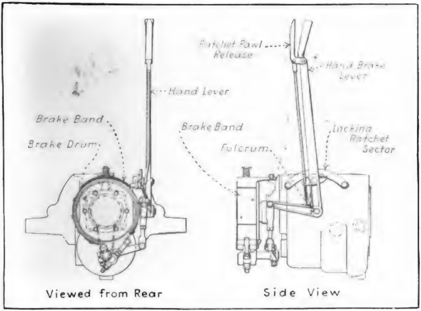


Fig. 278B.—Diagrams Showing Construction of Hand-Actuated External Constricting Band Brake Acting on Drum Attached to Driving Shaft at Rear of Change-Speed Gear Box.

All anti-friction bearings may be divided in two general classes, those employing balls to carry the load, as shown at A and B, Fig. 280, and the other types depicted at C and D, which utilize rollers. The ball bearing depicted at A is a cup and cone form, patterned somewhat after bearings that have received wide application in bicycles and numerous other light machines. This bearing has an angular contact, and is capable of taking radial and thrust loads. A radial load is one applied at a right angle to the center line of the shaft passing through the bearing cone,

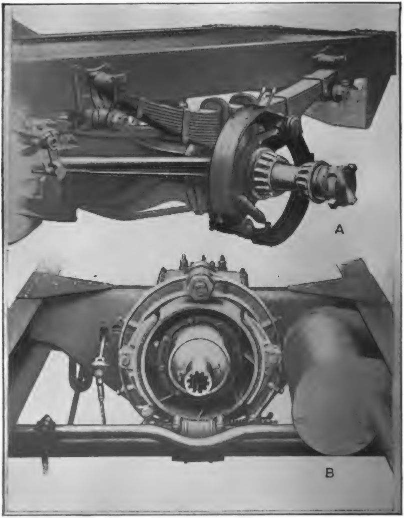


Fig. 279.—Internal Expanding Shoe Brake of Packard Truck at A. The Special "Caliper" or Clamping External Shoe Brake Used on Drive Shaft Shown at B.

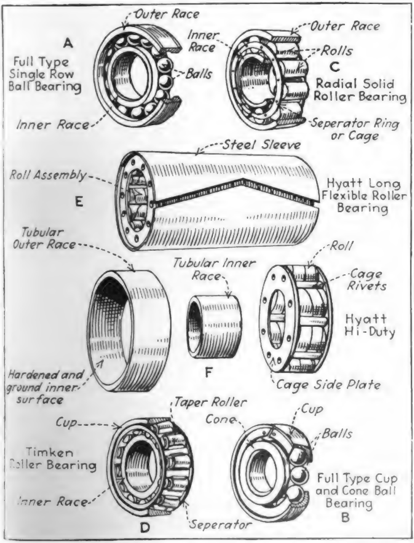

Outer Race
A
Full Type
Single Row
Ball Bearing
Inner Race
Balls
Inner Race
Outer Race
Rolls
C
Radial Solid
Roller Bearing
Seperator Ring
or Cage
Steel Sleeve
Roll Assembly
E
Hyatt Long
Flexible Roller
Bearing
Tubular
Outer Race
Roll
Tubular Inner
Race
Cage
Rivets
Hyatt
Hi-Duty
Hardened and
ground inner
surface
F
Cage Side Plate
Taper Roller
Cone
Cup
Cup
Balls
Timken
Roller Bearing
Inner Race
Full Type Cup
and Cone Ball
Bearing
B
D
Seperator

Fig. 280.—Common Types of Anti-Friction Bearings Used in Motor Truck Construction.

while an end thrust is a load that tends to push the cone laterally against the cup. An angular resultant is a load composed of a combination of end thrust and radial stress. A ball or roller bearing having angular line of contact is suited to resist either a radial or thrust load or a combination of the two. Angular contact bearings, or the cup and cone type, are adjustable to a certain degree, inasmuch as lost motion may be eliminated, if not due to bearing depreciation, by forcing the cup or cone into more intimate contact with the balls, providing the other member is held against a suitable shoulder in the housing or on the shaft. The ball bearing shown at B is an annular form having a vertical

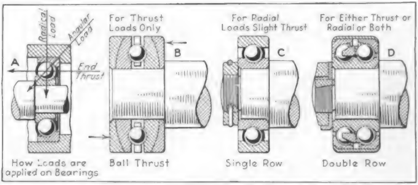

Radial Load
Angular Load
A
End Thrust
For Thrust Loads Only
B
For Radial Loads Slight Thrust
C
For Either Thrust or Radial or Both
D
How Loads are applied on Bearings
Ball Thrust
Single Row
Double Row

Fig. 281.—Types of Ball Bearings Used in Motor Truck Construction.

load line, and is thus adapted only for radial loads and very light end thrust.

The roller bearing shown at C is provided with straight rolls, and can only take radial loads just as the ball bearing shown at B. The roller bearing depicted at D, which employs tapered inner and outer race members and correspondingly tapered rollers, is capable of resisting end thrust as well as radial loads, but as is true of the cup and cone bearing depicted at A, the direction of the load must be such that the bearing parts will be forced more closely together. If a straight roller bearing or an annular

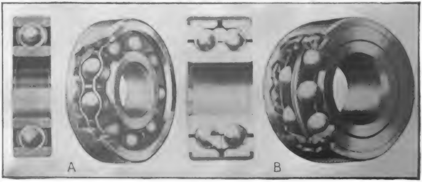


Fig. 282.—Cuts Showing Difference Between Single and Double Row Bearings.

Google

ball bearing having a vertical line of contact is used at points where considerable end thrust exists, it is necessary to apply another bearing to resist the thrust. A double row form of bearing, such as shown at D, Fig. 281, or B, Fig. 282, which

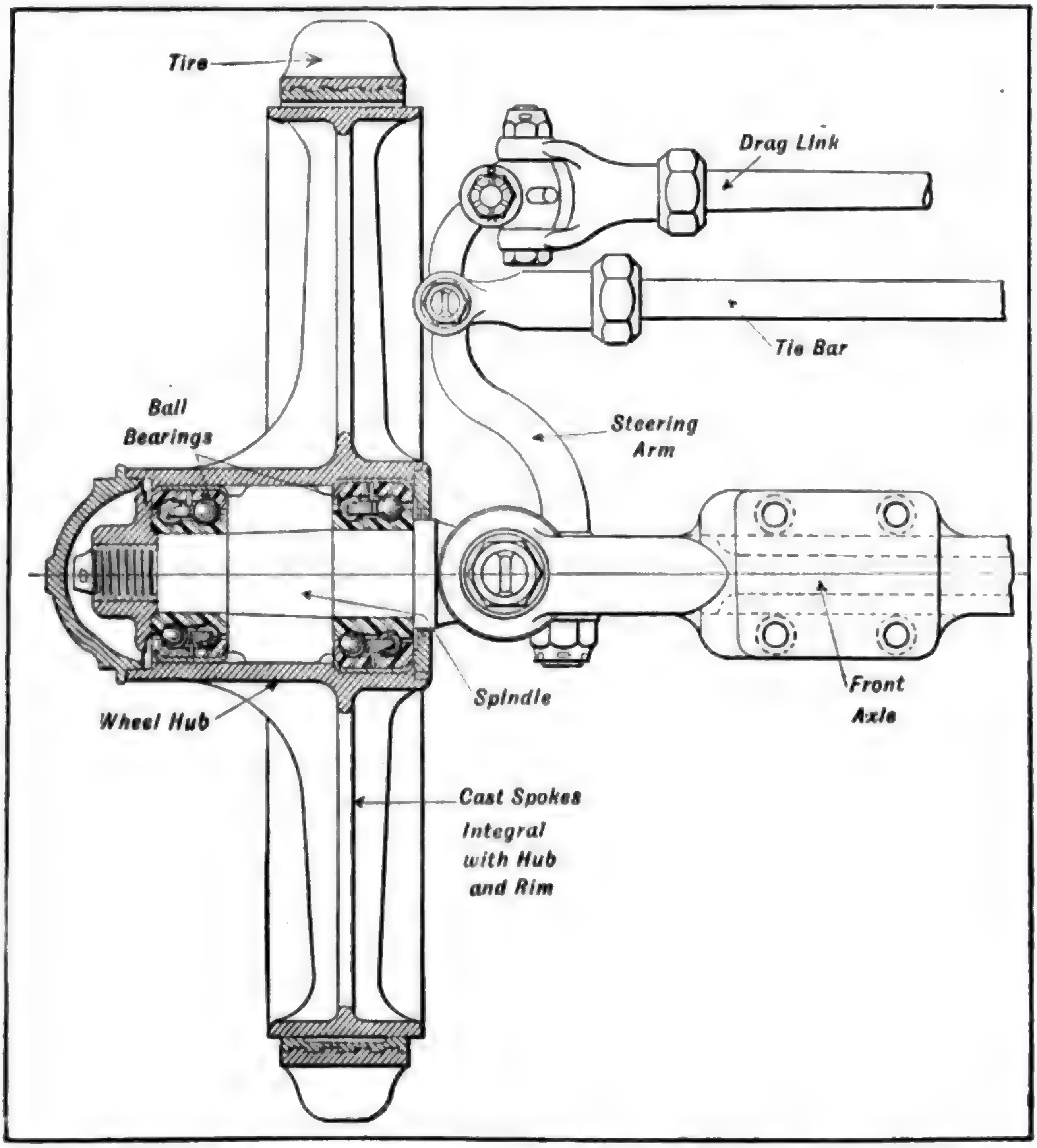

Tire
Drag Link
Tie Bar
Ball Bearings
Steering Arm
Spindle
Front Axle
Wheel Hub
Cast Spokes Integral with Hub and Rim

Fig. 283.—Front Wheel of Heavy Truck Mounted on Double Row Ball Bearings.

consists virtually of two cup and cone bearings mounted together in a common shell, has received general application because it can take the loads applied from any direction. The load lines are at an angle and diverge from the center line of the bearing outwardly. A radial load will be resisted by both rows of balls, while a thrust load from either direction will be sustained by the outer race and balls opposite the point of application, assuming that the outer race is held against an abutment or shoulder in the housing while the load is applied to the cone.

The angularity of a load line of a bearing affects radial end thrust capacity, depending upon the angle the load line assumes with the horizontal or vertical center lines of the bearing. As a bearing with a vertical load line has the greatest radial capacity and practically no resistance to end thrust, it follows that one with a horizontal load line will have the greatest thrust capacity and practically no resistance to radial loads. This is clearly shown at Fig. 281.

Roller bearings may be made with either solid or flexible rolls. A solid roller should be short in order to prevent deflection or distortion of the roll if the stress is not evenly applied. If long solid rollers are used, one end will tend to travel faster than the other, and this is apt to produce friction between the rolls and the retaining cage. It is contended by adherents of the flexible roll construction shown at Fig. 280, E, that this type adapts itself more readily to irregularities in shaft contour, and thus turns with less friction than do the solid rolls. The flexible roller bearings are made in two types, one employing long steel rolls, while the high duty type uses shorter rolls of high tensile strength alloy steel and accurately ground inner and outer race members. In the regular or long roll pattern the shaft itself is intended to form one bearing surface, and as this is generally soft, the rolls must be long in order to distribute the load over more surface. Flexible roller bearings are wound from strip stock, so that right and left spirals exist in alternate rollers, and the oil will be constantly circulated from one side of the bearing to the other.

In either ball or roller bearings the effect of the load is to flatten the supporting members a very small amount, so that in a roller bearing the contact between the roller and race-way may be represented by a rectangle having a length equal to the roll, but with a width so small that it is usually considered a line contact. In a ball bearing the flattening of the ball produces an ellipse of such small area that it is usually considered a point of contact. As the reduction of friction depends upon the amount of surface in contact, it can readily be understood that the form having the least amount of surface would have least friction. Ball bearings are generally employed where it is desirable to reduce friction to a minimum or where bearings must attain high speed. Roller bearings have been widely applied where bearings of relatively small diameter but of large carrying capacity must be used, where the shafts revolve at a comparatively low speed, and where maximum bearing efficiency is not important. The motor truck wheel shown at Fig. 283 is mounted on ball bearings of the double row form. Many other examples showing the practical application of all types of anti-friction bearings will be found at various points in this work.

Great care is needed to keep anti-friction bearings free from water or grit, and also to keep them adequately lubricated. The lubricant must be a pure mineral substance, and should not contain acid or animal fillers, because the highly polished surfaces of the anti-friction members and races will be roughened by etching or rusting due to chemical action, and this will interfere with smooth operation and tend to produce rapid depreciation. A heavy bodied lubricant of the semi-fluid type is best adapted for use in bearings subjected to heavy loads and revolving at low speed.

If an anti-friction bearing is housed in an oil-retaining, dust-excluding housing, it is good practice to use a medium grade machine oil and operate the bearings in a constant bath of lubricant. Ball or roller bearings should never be driven in place or removed with a steel drift or hammer, because the races are hard steel and are apt to be cracked unless they are forced in place either with a steady pressure, as by an arbor press, or by blows applied through the medium of a block of hard wood or piece of Babbitt metal interposed between the hammer and the bearing. The blow should always be directed or the pressure exerted against the race member that is being forced in place.

CHAPTER IX

MOTOR TRUCK LOADING AND OPERATION

Constant Inspection Important—Care Required in Loading—Table of Weights of Materials—Woods—Liquids—Grains and Produce—Miscellaneous Materials—Systematic Inspection Procedure—Inspection in Railway Practice — Instructions for Driver — Instructions for Washer—Instructions for Inspector—Inspection Schedule, Daily—Inspection Schedule, Weekly—Truck Lubrication Important—Motor —Fan, Magneto and Governor—Front Axle—Clutch and Transmission—Rear Axle—Springs and Chassis Parts—Specifications of Lubricants—Oiling Schedule for Commercial, One Ton Truck—Maintenance Routine, Daily—Maintenance Routine, Weekly—Maintenance Routine, Monthly—Typical Truck Chassis—Truck Oiling Schedules—Motor Truck Control Systems—Typical Control Systems, Winter—Nash Quad—Four Wheel Drive—Pierce-Arrow—Reo Speed Wagon—White Truck—Ford Model T Truck—To Start the Mack Truck Engine—Detailed Instructions for Mack Truck Operation—General Instructions for Packard Trucks—To Start the Motor —To Operate the Truck—To Stop the Motor—How to Operate the Autocar—Care and Operation of Bethlehem Trucks—Summary of Important Suggestions to Driver—Don'ts—Timely Hints for Good Service—Anti-Skid and Traction Devices—Extension Rims for Sand.

The success or failure of motor trucks in any business depends largely on the management of that business, which should make sure that the equipment is adequate for the purpose, that the type used is best adapted to the requirements of the individual enterprise, and that the loading and maintenance is intelligently supervised to make sure that the trucks will not be abused or depreciate rapidly because of lack of care. The capable transportation executive will consider the quantities and nature of the product coming to the transportation department and the best methods of handling and loading it at the source as well as its distribution to the destination. Working schedules should be devised that will keep the motor vehicles operating at a moderate speed and loaded most of the time they are in service. A motor vehicle should not be kept in operation more than ten hours out of twelve, because for at least two hours out of every twelve the vehicle should be cleaned, oiled and inspected.

Constant Inspection Important.—Each vehicle should be washed and the mechanism cleaned once every twenty-four hours. The truck user who is apt to think this an unnecessary procedure should remember that 60 per cent of the maintenance labor on locomotives goes for cleaning and that the average locomotive is thoroughly gone over by a trained corps of specialists every hundred or one hundred and fifty miles of travel. It is important to keep the vehicle clean, because if it is not kept clean it will be hard to locate loose or defective parts. Ample provision should be made for regular and systematic inspection of the trucks. If a fleet of trucks is operated, one or more spare trucks should always be available to take the place of any one that has broken down in service.

Care Required in Loading.—Special care should be taken in loading a truck so that its normal rated capacity is not exceeded unduly. The drivers should be cautioned to exercise good judgment in the matter of speed, as high speeds should only be used when the truck is operated on smooth roads and with light loads. While most trucks are built strong enough so that they may be greatly overloaded without breaking down at once, anyone who carries a 40 or 50 per cent overload continually will find that this is an expensive procedure from a viewpoint of cost of repairs. Tires, springs, wheel bearings, and the chassis members, such as frames and axles, are all stressed unduly if the truck is overloaded.

The distribution of the load should be kept so that 70 per cent to 80 per cent will be carried on the rear tires of most forms of trucks. In most designs the center of gravity of the load should be just a little ahead of the rear axle. If any of the load is removed from the rear of the truck the remainder should be distributed evenly and not kept bunched or concentrated at the front end of the body. The weight per cubic foot of different materials varies greatly, as shown in the table on p. 450. It will be evident that it may be possible to entirely fill the body with some material and still be under the rated capacity of the truck. Other substances, such as brick or metal ingots, may take up but a small portion of the cubical contents of the truck body and yet the load be greatly in excess of the normal rated capacity. This fact should be considered in loading all trucks. To figure the cubic capacity of any truck body, multiply the length in feet by the width in feet and the product of these two by the depth expressed in the same terms of measurement. The evil effect of overloading and poor load distribution is graphically shown at Fig. 284.

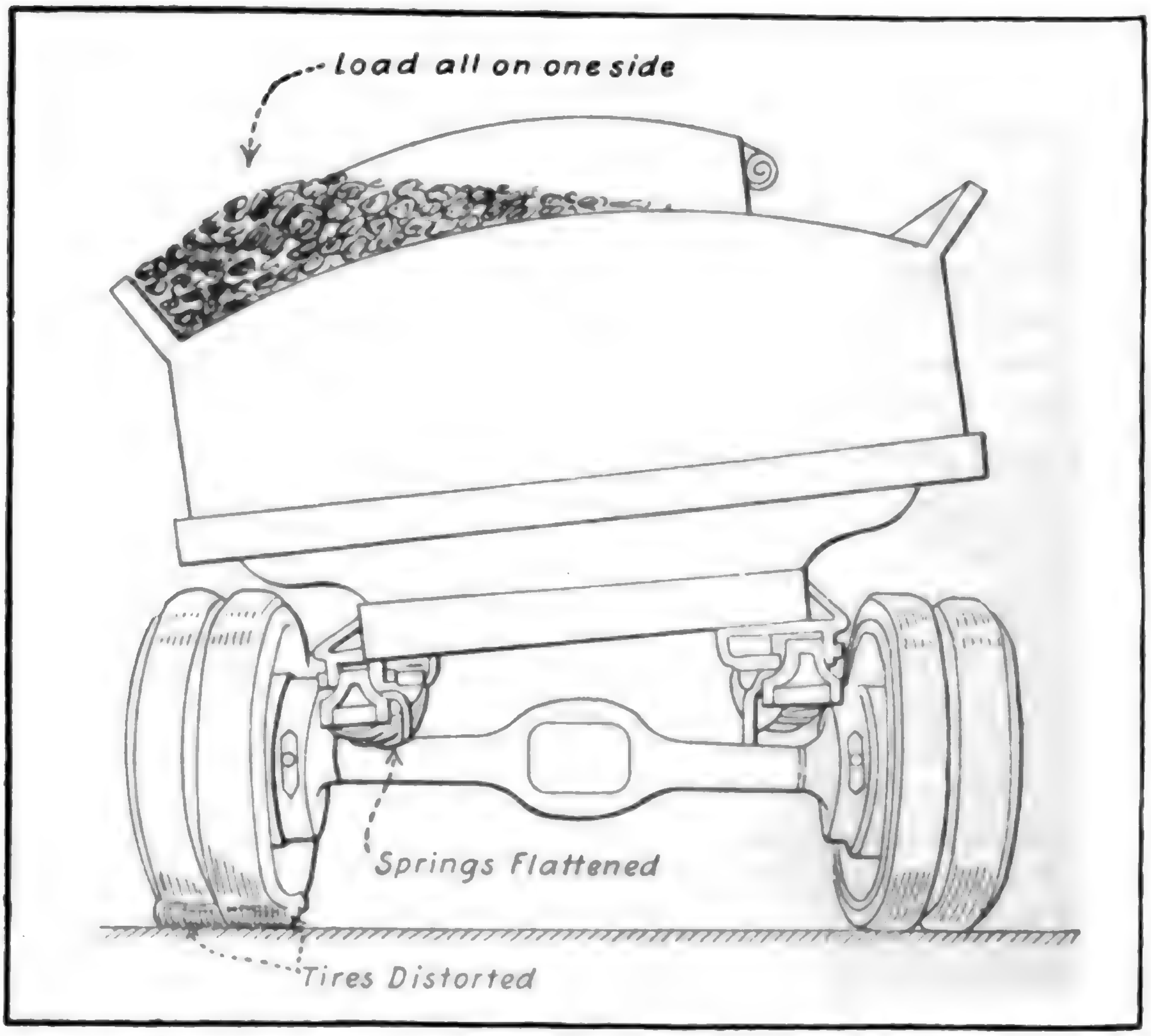


Fig. 284.—Diagram Outlining Evils of Overloading and Unequal Load Distribution on Motor Truck Frame Parts.

TABLE OF WEIGHTS OF MATERIALS AND MAXIMUM CAPACITY OF MODEL "B" F. W. D. 3-TON TRUCK

MATERIALS (WOODS)	Lbs. Per Cu. Ft.	Max. Cap. Bd. Ft.
Ash	46.8	1530
Basswood	28.2	2550
Beech	46.8	1530
Birch	43.1	1670
Cedar, Red	35.6	2020
Cherry	43.8	1640
Chestnut	37.4	1920
Cypress	37.4	1920
Elm	41.8	1720

MATERIALS (WOODS)	Lbs. Per Cu. Ft.	Max. Cap. Bd. Ft.
Fir	34.3	2090
Gum	35.6	2020
Hazel	37.4	1920
Hemlock	24.8	2900
Hickory	49.9	1440
Holly	47.5	1510
Linden	37.4	1920
Locust	45.7	1570
Mahogany	56.2	1280
Maple	43.8	1640
Mulberry	46.8	1530
Oak, Live	72.1	1000
Oak, Red	46.8	1530
Oak, White	49.9	1440
Pine, White	31.3	2300
Pine, Yellow	40.6	1770
Poplar	31.3	2300
Redwood, California	45.7	1570
Rosewood	66.3	1080
Spruce	28.2	2550
Sycamore	34.3	2090
Teak	53.1	1350
Walnut, American Black	40.6	1770
Walnut, Circassian	34.3	2090
Walnut, Persian	36.8	1950

LIQUIDS	Lbs. Per Cu. Ft.	Max. Cap. Gallons
Acetic Acid	66.3	676
Alcohol, Commercial	51.8	866
Ammonia	55.7	805
Benzine	43.1	1041
Carbolic Acid	59.9	748
Cotton Seed Oil	58.0	773
Gasoline	56.2	800
Kerosene	49.9	900
Lard Oil	56.8	790
Linseed Oil	58.7	765
Milk	61.4	730
Mineral Oil	53.7	770
Muriatic Acid	74.9	600
Naphtha	47.4	945
Nitric Acid	77.5	580
Petroleum Oil	51.2	875
Sulphuric Acid	114.9	400
Tar	63.35	720
Turpentine Oil	54.2	825
Water, Distilled	62.35	720
Water, Sea	64.4	700

GRAINS AND PRODUCE	Lbs. Per Cu. Ft.	Max. Load Cu. Yds.
Barley	38.4	5.8
Beans	48.0	4.6
Buckwheat	40.0	5.6
Clover Seed	48.0	4.6
Corn Meal	40.0	5.5
Corn, Shelled	44.8	5.0
Oats	25.6	8.6
Onions	45.6	4.9
Potatoes	48.0	4.6
Rye	44.8	5.0
Timothy Seed	36.0	6.1
Turnips	44.0	5.0
Wheat	48.0	4.6

MATERIALS (MISC.)	Lbs. Per Cu. Ft.	Max. Cap. Cu. Yd.
Asbestos	174.5	1.12
Asphaltum	87.3	2.54
Borax	109.1	2.03
Brick, Common	112.4	1.97
Brick, Fire	143.7	1.54
Brick, Hard	124.7	1.78
Brick, Pressed	134.1	1.65
Brick, Soft	99.8	2.22
Brickwork, in Cement	112.4	1.97
Brickwork, in Mortar	99.8	2.22
Cement, Portland, Loose	69.8	3.18
Charcoal	25.0	8.33
Coal, Anthracite	93.8	2.26
Coal, Bituminous	79.1	2.80
Coke	28.0	7.92
Earth, Loose	774.9	2.96
Earth, Rammed	99.8	2.22
Granite	165.5	1.34
Gravel	109.1	2.02
Gypsum	137.0	1.62
Ice	56.2	3.96
Lime	53.1	4.18
Limestone	162.2	1.37
Marble	169.3	1.31
Masonry	149.8	1.48
Mica	174.5	1.27
Mortar	93.7	2.37
Phosphorus	112.4	1.97
Plaster Paris	112.4	1.97
Quartz	162.2	1.37
Salt, Common	131.3	1.69

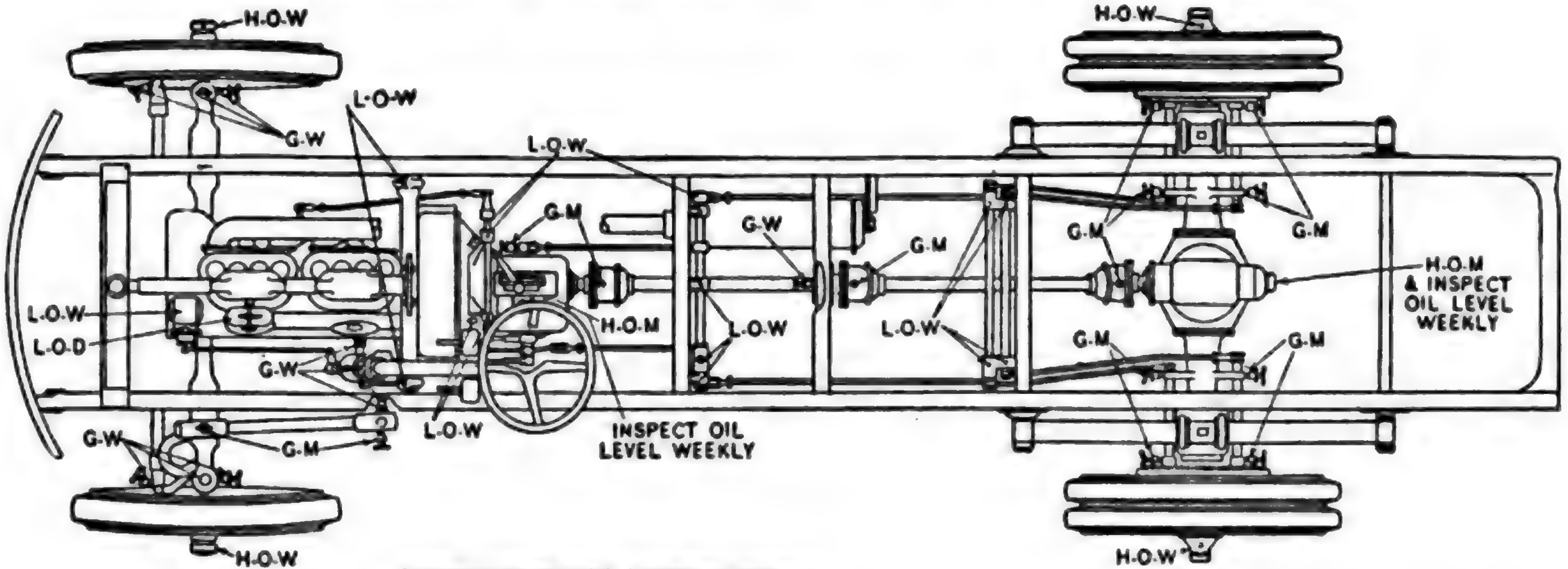
MATERIALS (MISC.)	Lbs. Per Cu. Ft.	Max. Cap. Cu. Yd.
Sand, Dry	99.8	2.22
Sand, Wet	124.7	1.78
Sandstone	143.7	1.54
Slate	174.5	1.27
Soil, Black	124.7	1.78
Stone, Crushed	99.8	2.22
Sulphur	124.7	1.78
Terra Cotta	109.8	2.02
Tile	112.4	2.11
Trap Rock	169.8	1.40

Systematic Inspection Procedure.—In the instruction book for Mack Motor Trucks, issued by the International Motor Co. of New York City, valuable suggestions are given for anyone responsible for care and operation of Mack trucks, that apply just as well to all makes because they are based on sound judgment and good common sense. The instructions are issued for the driver, the washer and the inspector, and advice is given for a systematic inspection schedule that is admirable for its thoroughness. As this is based on an extended experience, one cannot do better than reproduce them in full, which is done through the courtesy of the originators.

With slight changes to allow for differences in construction, those responsible for the economical operation of any make of truck could follow some such schedule to good advantage and organize their working forces so a definite task could be assigned each individual Where trucks are operated in fleets there should be ample provision made for an adequate working force, part of which is concerned only with driving, the remainder responsible for maintenance and inspection. When only a few trucks are operated, one man may have to combine several duties, but it is poor economy to save wages and pay more for repairs and depreciation as a consequence.

Inspection in Railway Practice.—The average driver or truck owner does not appreciate the need for systematic inspection and oiling of automobiles to secure best results. In railroad practice an express locomotive is inspected at the end of every 80 to 100 miles run; the freight engine is gone over every 150 or 200 miles. The work is so systematically done that as many as five or six inspectors may be working on the locomotive at once, as each is responsible for certain groups of parts. As a result of this

MACK "AB" WORM DRIVE TRUCKS-1-1½-2-TONS


H.O.W
L.O.W
G.W
L.O.W
G.M
G.W
G.M
L.O.W
L.O.D
G.W
H.O.M
L.O.W
L.O.W
G.W
G.M
L.O.W
INSPECT OIL
LEVEL WEEKLY
H.O.W
G.M
G.M
G.M
G.M
H.O.M
& INSPECT
OIL LEVEL
WEEKLY
H.O.W
H.O.W

DIRECTIONS FOR LUBRICATING

O. INDICATES OIL	
G -	GREASE
L -	LIGHT
H -	HEAVY
D -	DAILY
W -	WEEKLY
M -	MONTHLY

OIL SPECIFICATIONS

	GRAVITY	COLD TEST	FLASH	VISCOSITY
LIGHT OIL	21 OR 24	0 OR 10	375° OR 385°	OR 229 AT 10 215 10
HEAVY -	26.4	40	540°	125 - 210
GREASE ANY GOOD SOFT CUP GREASE				

IF DIFFICULTIES OCCUR REFER TO
NEAREST INTERNATIONAL MOTOR CO.
SERVICE STATION, OR TO
A. F. MASURY, CHIEF ENGINEER,
INTERNATIONAL MOTOR CO.
64TH ST. & WEST END AVE.,
NEW YORK

MOTOR:—OIL DAILY. OPEN OIL LEVEL COCK IN LOWER CRANK CASE. POUR OIL INTO TANK AT SIDE OF FRONT CYLINDER UNTIL IT FLOWS OUT OF OIL LEVEL COCK, OR UNTIL INDICATOR REACHES THE REQUIRED MARK. LOCK OIL TANK COVER TIGHTLY AND CLOSE OIL LEVEL COCK BEFORE STARTING.

CLEANING:—CANNOT BE DONE TOO THOROUGHLY AND OFTEN.

REAR AXLE:—KEEP OIL LEVEL WITH LOWER EDGE OF FILLER OPENING:—INSPECT WEEKLY.

TRANSMISSION:—KEEP OIL LEVEL 10¼ IN. BELOW EDGE OF FILLER OPENING IN 3 SPEED AND 6¼ IN. IN 4 SPEED. INSPECT WEEKLY.

Fig. 285.—Lubrication Diagram for Mack "AB" Worm Drive Trucks.

careful inspection, passenger locomotives run about 125,000 miles without an overhauling and freight engines 100,000 miles. When a motor truck or automobile chassis receives periodical inspection, cleaning and lubrication, its life is greatly increased and liability of breakdown on the road is reduced to a minimum. When one considers that the usual truck or car is not driven by an expert, or over smooth steel rails as the locomotives are, the importance of giving the mechanism proper attention to insure uninterrupted motor transportation should be apparent to the least technically-minded.

INSTRUCTIONS FOR THE DRIVER

A. Before you take the truck out of garage, do the following work and make a record on your daily report:

1. Fill gasoline tank. Fill radiator. Fill oil tank (see lubricating instructions).
2. Turn up grease cups until they meet decided resistance and grease issues from sides of bearing. If empty, refill.
3. Oil brake rod clevises, fan bearing, pedal clevises, speed levers, radiator supporting pins, and all parts provided with oil holes.
4. Clean and fill oil lamps.
5. Make sure that troubles reported have been corrected.

B. When you bring truck into garage—

1. Wipe engine clean.
2. Make out daily report card. Report any parts that have given trouble that day.

On Saturday

C. 1. Follow "Weekly" Lubricating Instructions.

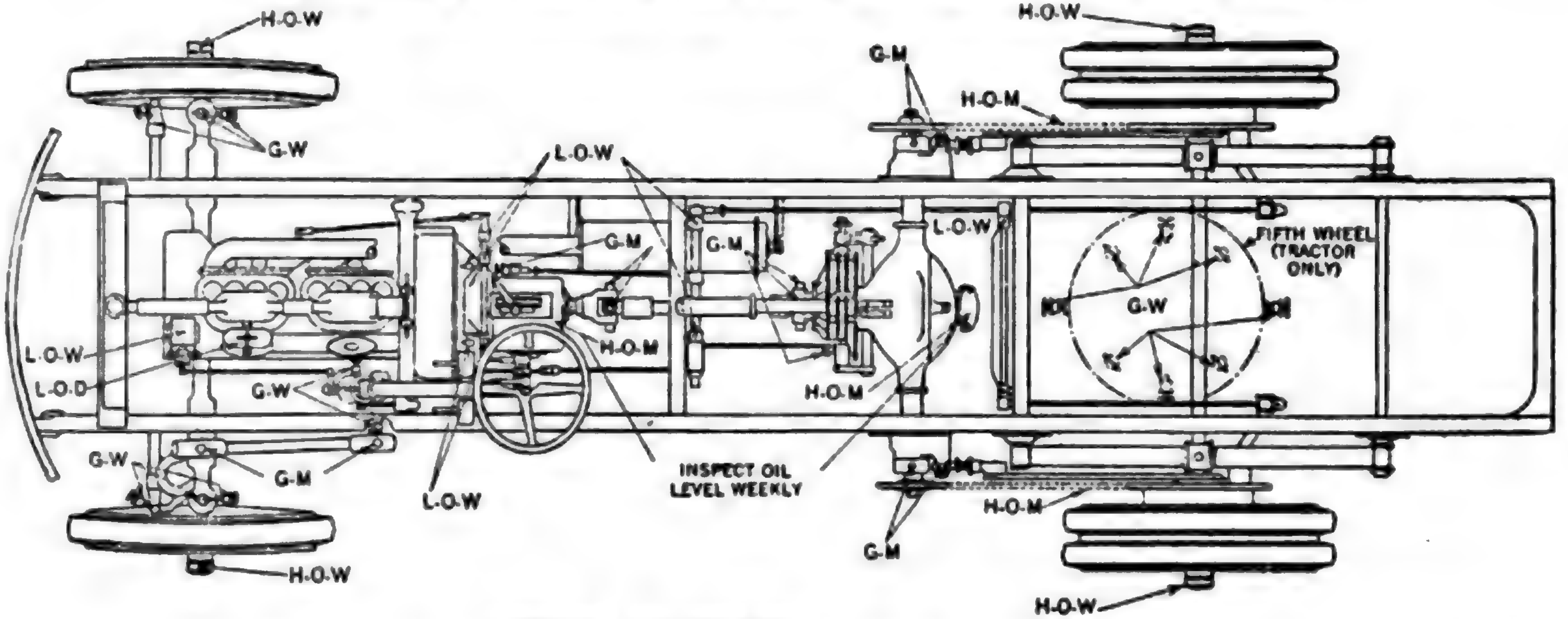
2. Pour one fluid ounce of kerosene into the combustion chambers of each cylinder while engine is warm and let stand over night.

Every Two Months

D. Follow "Two Months" Lubricating Instructions.

Wash or clean a motor truck every time it comes into the garage.

MACK "AB" CHAIN DRIVE TRUCKS - 1 - 1½ - 2 - TONS



DIRECTIONS FOR LUBRICATING

O	INDICATES	OIL
G	"	GREASE
L	"	LIGHT
H	"	HEAVY
D	"	DAILY
W	"	WEEKLY
M	"	MONTHLY

OIL SPECIFICATIONS

	GRAVITY	COLD TEST	FLASH		VISCOSITY		
LIGHT OIL—	21 OR 24	0 OR 10	375° OR 385°	OR	224 215	AT	100° 104°
HEAVY " —	26.4	40	540°		125		210°
GREASE—ANY GOOD SOFT CUP GREASE							

IF DIFFICULTIES OCCUR REFER TO
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MOTOR:—OIL DAILY, OPEN OIL LEVEL COCK IN LOWER CRANK CASE. POUR OIL INTO TANK AT SIDE OF FRONT CYLINDER UNTIL IT FLOWS OUT OF OIL LEVEL COCK, OR UNTIL INDICATOR REACHES THE REQUIRED MARK. LOCK OIL TANK COVER TIGHTLY AND CLOSE OIL LEVEL COCK BEFORE STARTING.

CLEANING:—CANNOT BE DONE TOO THOROUGHLY AND OFTEN.

DIFFERENTIAL:—KEEP OIL LEVEL WITH LOWER EDGE OF FILLER OPENING: INSPECT WEEKLY.

TRANSMISSION:—KEEP OIL LEVEL 10½ IN. BELOW EDGE OF FILLER OPENING IN 3 SPEED AND 9½ IN. IN 4 SPEED. INSPECT WEEKLY.

CHAINS:—CLEAN AND OIL A LITTLE.

8 AB 31

Every 1500 miles drain crankcase completely, flush with kerosene and refill.

Fig. 286.—Lubrication Diagram of Mack "AB" Chain Drive Trucks.

INSTRUCTIONS FOR THE WASHER

In dirty weather a truck should be washed as soon as it comes in. If dirt gets hard it's a big job to get it off. If grease does not come off with water and soap, use gasoline and a scraper.

Don't stop when you have washed the body and the parts that can be seen from the outside.

Get in under the truck with a light and clean the running gear so that the inspector can tell if the nuts and cotter-pins are on the ends of the bolts.

Do not clean the motor. This is the driver's job.

After washing, wipe off the parts that will rust.

Clean a truck thoroughly every time it comes into the garage; your work will be that much lighter the next time you have to clean it.

INSTRUCTIONS FOR THE INSPECTOR

To be of value the inspection of motor vehicles must be systematic and thorough.

Trucks should be inspected as soon as they have been cleaned.

Take driver's daily card and check up his report. Order necessary repairs and proceed at once with inspection of balance of chassis.

For your own protection you should make a record of the parts—

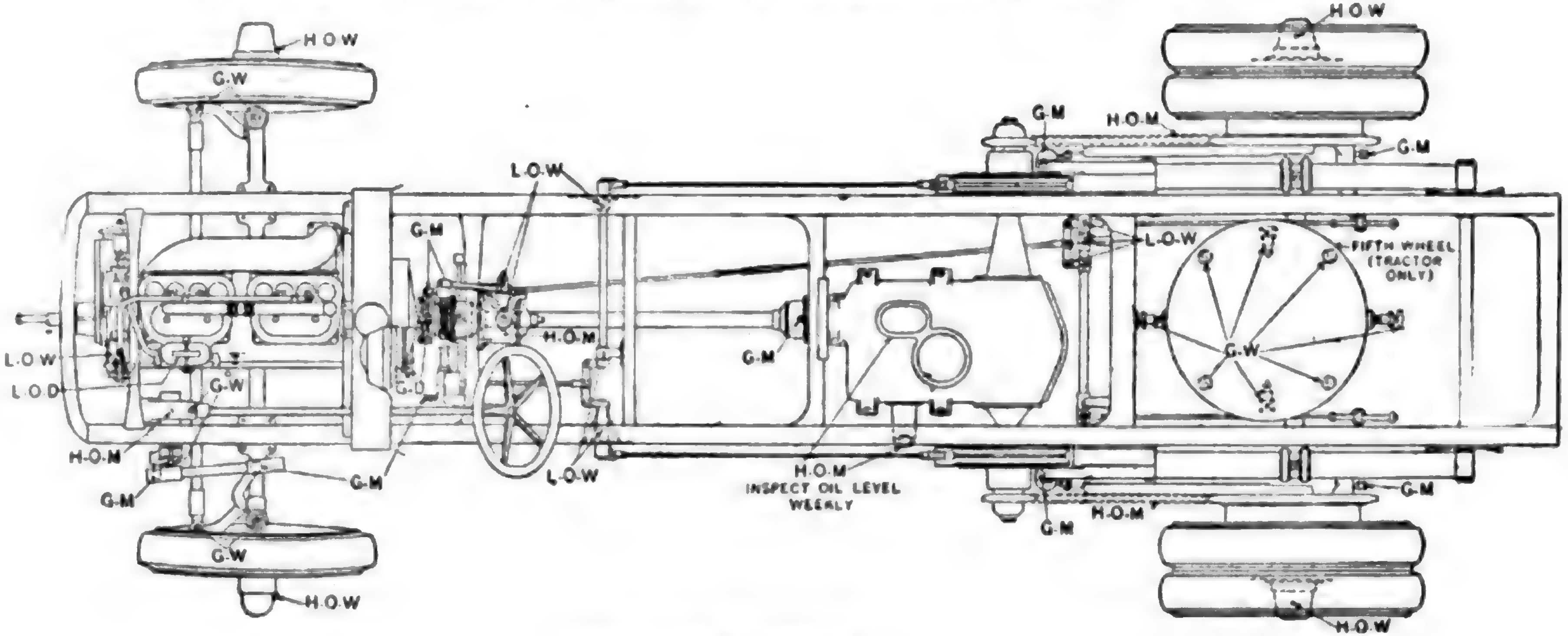
1. That you have found dry, and have oiled.
2. That you have found loose, and have tightened.
3. That you have found worn, and have repaired or replaced.
4. That you have found broken, and have repaired or replaced.

A gasoline motor truck is a power plant on wheels. Like any other power plant, stationary engine, marine engine, or locomotive, its operation is dependent upon auxiliaries (or auxiliary systems) which must be cleaned, inspected and adjusted at fixed intervals in order to obtain satisfactory results.

These auxiliaries are:

No. 1—Fuel system.
No. 2—Exhaust system.
No. 3—Cooling (or water circulating) system
No. 4—Ignition system.
No. 5—Lubrication system.

MACK "AC" CHAIN DRIVE TRUCKS - 3½ - 5½ - 7½ - TONS


H.O.W
G.W
L.O.W
G.M
H.O.M
G.M
H.O.M
G.M
L.O.W
FIFTH WHEEL (TRACTOR ONLY)
G.W
L.O.W
L.O.D
G.W
G.D
G.M
H.O.M
G.M
G.M
L.O.W
H.O.M
INSPECT OIL LEVEL WEEKLY
G.M
H.O.M
G.M
G.W
H.O.W
H.O.W

—DIRECTIONS FOR LUBRICATING—

O	INDICATES	OIL
G	"	GREASE
L	"	LIGHT
H	"	HEAVY
D	"	DAILY
W	"	WEEKLY
M	"	MONTHLY

OIL SPECIFICATIONS

	GRAVITY	COLD TEST	FLASH		VISCOSITY	AT
LIGHT OIL—	21 OR 24	0 OR 10	375° OR 385°	OR	224 215	100° 104°
HEAVY " —	26.4	40	540°		125	210°
GREASE — ANY GOOD SOFT CUP GREASE						

MOTOR.— OIL DAILY. OPEN OIL LEVEL COCK IN LOWER CRANK CASE. POUR OIL INTO TANK AT SIDE OF FRONT CYLINDER UNTIL IT FLOWS OUT OF LEVEL COCK, OR UNTIL INDICATOR REACHES THE REQUIRED MARK. LOCK OIL TANK COVER TIGHTLY AND CLOSE OIL LEVEL COCK BEFORE STARTING.

CLEANING:—CANNOT BE DONE TOO THOROUGHLY AND OFTEN.

TRANSMISSION:—KEEP OIL LEVEL WITH LOWER EDGE OF FILLER OPENING—INSPECT WEEKLY.

CHAINS—CLEAN AND OIL A LITTLE.

IF DIFFICULTIES OCCUR REFER TO NEAREST
INTERNATIONAL MOTOR COMPANY SERVICE STATION, OR TO
A. F. MASURY, CHIEF ENGINEER,
INTERNATIONAL MOTOR COMPANY
64TH ST. & WEST END AVENUE
NEW YORK CITY

6 AC 41 B

Fig. 287.—Lubrication Diagram of Mack "AC" Chain Drive Trucks.

The piping and wiring used in these systems perform the same functions as the piping and wiring in a house or a factory, and in addition are subjected to deterioration from excessive vibration, dirt and exposure.

If you do not keep the parts of a motor truck clean, it is impossible to tell whether or not the connections are tight. If you do not keep the connections tight, leaks will develop and ultimately some of the parts will fall into the road.

Do not attempt to improve the adjustment of any of the parts so long as the connections are tight and they perform their work properly. Do not attempt to run an engine with the governor disconnected.

INSPECTION SCHEDULES

Monday

1. Tires.
2. Brakes and connections.
3. Spring clips.
4. Steering connections.
5. Chains.
6. Gasoline System—
    - (a) Gasoline Tank.
    - (b) Gasoline Filter and Drain Cock—CLEAN.
    - (c) Gasoline Pressure Gauge.
    - (d) Gasoline Regulator.
    - (e) Gasoline Priming Rod.
    - (f) Gas Inlet Manifold.
    - (g) Carburetor (examine gasoline record of truck since last setting, and adjust if necessary).
    - (h) Hot Air Intake Pipe.

Tuesday

1. Tires.
2. Brakes and connections.
3. Spring clips.
4. Steering connections.
5. Chains.
6. Exhaust System:
    - (a) Exhaust manifold.
    - (b) Exhaust pipe.
    - (c) Muffler and connections.

7. Cooling System:
    - (a) Radiator.
    - (b) Water Manifold.
    - (c) Water pump.
    - (d) Water pump coupling and block.
    - (e) Water Hose Connection.
    - (f) FAN AND FAN BELT (if fan is repaired, see that it is properly balanced up again).

Wednesday

1. Tires.
2. Brakes and connections.
3. Spring clips.
4. Steering connections.
5. Chains.
6. Ignition System:
    - (a) Magneto fastenings (see Magneto Instructions).
    - (b) Magneto coupling and block.
    - (c) Timer.
    - (d) Wire and housing clean and free from oil.
    - (e) Coil.
    - (f) Switches.
    - (g) Batteries.
    - (h) Insulators.
    - (i) Spark Plug connection.

Thursday

1. Tires
2. Brakes and connections.
3. Spring clips.
4. Steering connections.
5. Chains.
6. Oiling System:
    - (a) Lid and screen of oil distributor tank on front cylinder.
    - (b) Gauge on dash.
    - (c) Oil pipes and connections.
    - (d) Crankcase for leaks.
    - (e) Oil pump drive.

7. CLUTCH:
    - (a) Adjustment of clutch and clutch brake.
    - (b) Play in universal joints.
    - (c) Lubricant in joints.

Friday

1. Tires.
2. Brakes and connections.
3. Spring clips.
4. Steering connections.
5. Chains and sprockets.
6. Steering gear and attaching bolts.
7. Pedals and shafts to clutch and brake.
8. Control levers and shafts to transmission and brake.
9. Rivets and bolts in frame.
10. Bolts and screws attaching tool box, lamps, license brackets and tags, horn, mirror, glass front, and other accessories.
11. Bolts and screws in body and cab, dash, hood and radiator supports.

First Saturday in Every Month

1. See that vehicle is thoroughly cleaned up. Driver is responsible for motor; washer for balance of vehicle.
2. Clean and lubricate magneto.
3. Examine, make and break and adjust if necessary. (See Magneto Instructions in chapter on Ignition.)
4. Examine and adjust spark plugs for 1/50 inch gap. Test the spark in each cylinder by disconnecting the spark plug cables of the three other cylinders.
5. Examine adjustment of valve tappets.
6. Test compression of each cylinder.
7. Remove chains, wash in kerosene. When clean, soak for a few minutes in hot tallow. Drain excess tallow.
8. Replace and adjust chain. The adjustment is correct when chain can be lifted 1½ to 2 inches.

(On shaft-driven models omit 7 and 8.)

Second Saturday in Each Month

1. See that vehicle is thoroughly cleaned up. Driver is responsible for motor; washer for balance of vehicle.
2. Clean and lubricate magneto.

3. Examine make and break and adjust, if necessary. (See Magneto Instructions.)
4. Examine and adjust spark plugs for 1/50-inch gap. Test the spark in each cylinder by disconnecting the spark plug cables of the three other cylinders.
5. Examine adjustment of valve tappets.
6. Test compression of each cylinder.
7. Clean oil strainer in crankcase.
8. Grind valves, if necessary.

Third Saturday in Each Month

1. See that vehicle is thoroughly cleaned up. Driver is responsible for motor; washer for balance of vehicle.
2. Clean and lubricate magneto.
3. Examine make and break and adjust, if necessary.
4. Examine and adjust spark plugs for 1/50-inch gap. Test the spark in each cylinder by disconnecting the spark plug cables of the three other cylinders.
5. Examine adjustment of valve tappets.
6. Test compression of each cylinder.
7. Remove chains, wash in kerosene. When clean, soak a few minutes in hot tallow. Drain excess tallow.
8. Remove rear wheels.
9. Examine wheel bearings.
10. Examine rear axle brakes.
11. Examine radius rod mounting and bearings.
12. Grease and replace wheels.
13. Replace and adjust chain, adjustment correct when chain can be lifted 1½ to 2 inches.

(On shaft-driven models omit 7 and 13.)

Fourth Saturday in Each Month

1. See that vehicle is thoroughly cleaned up. Driver is responsible for motor; washer for balance of vehicle.
2. Clean and lubricate magneto.
3. Examine make and break and adjust, if necessary.
4. Examine and adjust spark plugs for 1/50-inch gap. Test the spark in each cylinder by disconnecting the spark plug cables of the three other cylinders.
5. Examine adjustment of valve tappets.

6. Test compression of each cylinder.
7. Examine amount of oil and grease in transmission case. Fill, if necessary.
   (Every two months put in new.)
8. Examine condition of steering gear and check up alignment of front wheels.
9. Carefully test engine for knocks, irregular running, condition of bearings and adjustments.

Fifth Saturday in Months Which Contain Five Saturdays (Five Times Per Year)

1. See that vehicle is thoroughly cleaned up. Driver is responsible for motor; washer for balance of vehicle.
2. Clean and lubricate magneto.
3. Examine make and break and adjust, if necessary.
4. Examine and adjust spark plugs for 1/50-inch gap. Test the spark in each cylinder by disconnecting the spark plug cables of the three other cylinders.
5. Examine adjustment of valve tappets.
6. Test compression of each cylinder.
7. Clean carbon, grind valves, time valves, take up bearings or other work on motor that may be necessary, as indicated by inspection on fourth Saturday. The inspector, however, must use his judgment and not leave too much of this work for fifth Saturday.

Truck Lubrication Important.—Without question, the subject of lubrication is of much more importance to you as an owner and to us as manufacturers than any other subject upon which we have touched, say the makers of the Winther truck. To you, because proper lubrication contributes in no small degree to keeping your investment at its maximum earning capacity; to us, because our success depends in a more or less degree on how well the truck performs for you; and, notwithstanding the fact that "Winther" trucks are honor built; that the best of workmanship and highest grade materials that money can buy are employed in their manufacture, they cannot give you the service that you have the right to expect if this feature is neglected.

The best of material will not lubricate a bearing, and the finest workmanship will not keep your truck out of the scrap heap, if wearing surfaces are not lubricated regularly. Even slight neglect, not in itself serious enough to immediately destroy, will have damaging effect upon wearing parts, and will cause not only increased depreciation, but lost time, increased maintenance and operating cost, and a performance not at all in keeping with that the truck was designed and constructed to give.

Assuming, then, that we have honestly striven to fulfill our part, that your satisfaction may be assured, by delivering to you in good condition a truck that is up to standard, may we not ask you to do your part by following carefully the lubricating instructions given?

The instructions which follow apply to the Winther truck, though in many respects they can be followed to advantage by drivers and owners of other standard trucks.

Motor.—The oil reservoir, when empty, will take two gallons, one pint of oil. Oil heavy in weight, light in color, is recommended. Mobiloil is in the motor when truck leaves the factory. The oil filler will be found located at forward end of the Winther motor on the right side. Care should be exercised at all times to see that the oil is kept between high and low marks on gauge located at rear end of motor on right side. Watch the oil circulation indicator on dash carefully, and should it not register when motor is running investigate immediately, ascertaining if the oil line is stopped up, or if the reservoir is empty.

The oil reservoir should be drained every five hundred miles through the plugs located at rear of reservoir in the bottom of crankcase, and refilled with fresh oil. The reason for this is obvious; the grade of gasoline that is being merchandised at the present time is such that perfect carburetion is impossible until the motor warms up, resulting in considerable gasoline finding its way into the oil reservoir, which gradually thins the oil until it ceases to be a perfect lubricant.

The oil system is of the force feed type, and pressure is maintained by a positive gear-driven pump located in the rear end of oil reservoir on left side. There is an oil strainer surrounding the pump which should be cleaned occasionally. This can be easily removed for cleaning by simply taking out the four cap screws.

Fan.—A grease cup is provided. Fill weekly with grease; turn every day.

Magneto.—Do not overoil. One or two drops of three-in-one oil injected into the oil wells every thousand miles will be sufficient. One of these wells is located on the top of the distributor housing, oiling the armature ball bearing, the distributor plain bearing and the oil wick in the timing lever body. The other oil well will be found on the extension of the end plate near the driving axle, and lubricates the ball bearing on that end of the magneto.

Governor.—Remove the oil filler screw and fill chamber weekly, using medium heavy cylinder oil, 600-W is preferable for summer, and in winter add to it an equal amount of light machine oil. Every 500 miles remove drain screw, filling half full of very light machine oil, run for an hour to clean interior and drain out. Refill the chamber with a good grade of medium heavy cylinder oil. Be sure the governor does not run without oil, as it might injure its bearings. Keep screws with copper washers tight to prevent oil leaking. Connect with wire to prevent losing them. See that the engine drives are well lubricated by regularly filling the oil and grease cups.

Front Axle.—Grease cups are provided at all points where friction comes. Make positive that the grease cups are filled with a high grade light grease positively free from acid and grit. Keep your supply of grease in a tightly covered can, so that no grit or dust can get into it.

The bearings in the front wheel are Timken, and may be lubricated with any light grease or heavy oil if it is positively free from acid. Plugs are provided in the wheel for lubricating the bearings, and in addition the wheels should be removed periodically, the bearings thoroughly cleaned with gasoline and relubricated with light grease, using clean paddle for spreading.

Transmission.—The transmission should be filled to about 1½ inch above center line of the main shaft with a good grade of heavy transmission grease.

Clutch.—No lubrication of the clutch is necessary, except that the clutch throwout bearing should receive regular lubrication. This is provided for by a large grease cup located on the floor board, which should be given one turn every morning or noon.

Steering.—Oil cups are provided and they should be kept filled with a good grade of light oil. At each end of the drag link is a socket in which the ball of the steering arm operates, as well as the arm on the knuckle arm. These should be thoroughly greased at least twice a month.

Rear Universal Joints.—Grease weekly with a good grade of cup grease, using grease gun, and once every three months joints should be completely taken down, thoroughly cleaned and repacked.

Rear Axle.—Axle has been thoroughly lubricated when delivered from plant. This should be sufficient lubrication for the first month, except two grease cups on the axle on front side just inside of brake drum. These should be kept packed with a medium thick grease and given a turn every day.

Oil cups on brake flanges should be given a little oil once a week. These lubricate the internal brake cams.

All external brake joints should be given a few drops of oil once a week.

Large internal gear inside of brake drum and bolted to wheel should be lubricated once every month by removing wheel and applying a new coating of grease to the teeth. This must be a very heavy grease which will not flow under any conditions of heat. If grease cannot be obtained thick enough, mix graphite with it until it is thick. Put on no more grease than just sufficient to cover the faces of the teeth lightly. If more is put on, it will interfere with the action of the brakes and will leak out, giving the wheels an untidy appearance. A hand hole is provided on the larger models for inspecting and lubricating the internal gear.

Fill differential gearcase one-third full of heavy oil or very light grease. Do not fill over one-third full.

Every six months take one drain cap in the bottom of case and thoroughly rinse out old grease with kerosene by pouring in at top cap. After rinsing out with kerosene, then fill with lubricant, as above instructed.

Hub bearings can be given sufficient grease by simply removing hub cap and filling this with grease, then screwing them back on in position. This should be done about every three months. When wheel is removed for lubricating internal gears, thoroughly wash out hub bearings with kerosene and gasoline, applying new lubricant. Pipe plugs will be found located on outside of hub; medium weight grease should be applied weekly, utilizing a grease gun for this purpose.

Springs.—Every six months the springs should be taken apart and lubricated with a good grade of grease mixed with graphite. Spring bolt bearings are provided with oil cups and should be oiled daily.

Miscellaneous.—There are numerous other points of friction such as control rods, cross rods, rocker shafts, etc., not mentioned, where a drop of oil occasionally will materially benefit. The one operating the truck should familiarize himself with these points where slight friction comes, and see that they receive the attention they require.

Specification of Lubricants.—After each part mentioned in lubricating instructions which follow for the Commerce one-ton truck, and indicated on the lubricating chart, will be found a reference number which indicates the kind of oil or grease best suited to the lubricating needs of each part. The meaning of the various figures is explained below:

Ref. No.	Lubricant
2-A.	Engine oil, medium, E. M. Specification No. 3502.
2-B.	Engine oil, heavy, E. M. Specification No. 3502.
4.	Heavy, straight mineral gear compound, E. M. Specification No. 3504.
5.	Light cup grease, E. M. Specification No. 3505.
6.	Medium cup grease, E. M. Specification No. 3506.
8.	Heavy, straight mineral oil, E. M. Specification No. 3508.
9.	Steam cylinder oil, 600-W, E. M. Specification No. 3509.

The specification numbers given refer to U. S. Government specifications in vogue during the war.

Study the lubricating chart for parts that require attention. Perfect and continuous lubrication means less wear of parts, less trouble and a better running truck. Lubricant is of little value mixed with dirt, so before you oil or grease a part make sure there is no dirt on the surfaces, that not even the smallest speck of dirt gets to a moving part.

Use clean cloths to wipe these surfaces after they have been cleaned by means of gasoline or kerosene. Make periodic lubrication a habit. Attend to certain parts daily, as indicated on the lubricating charts, Figs. 288 and 289, to others weekly and others monthly. These are maximum periods. D, W and M indicate the respective periods.

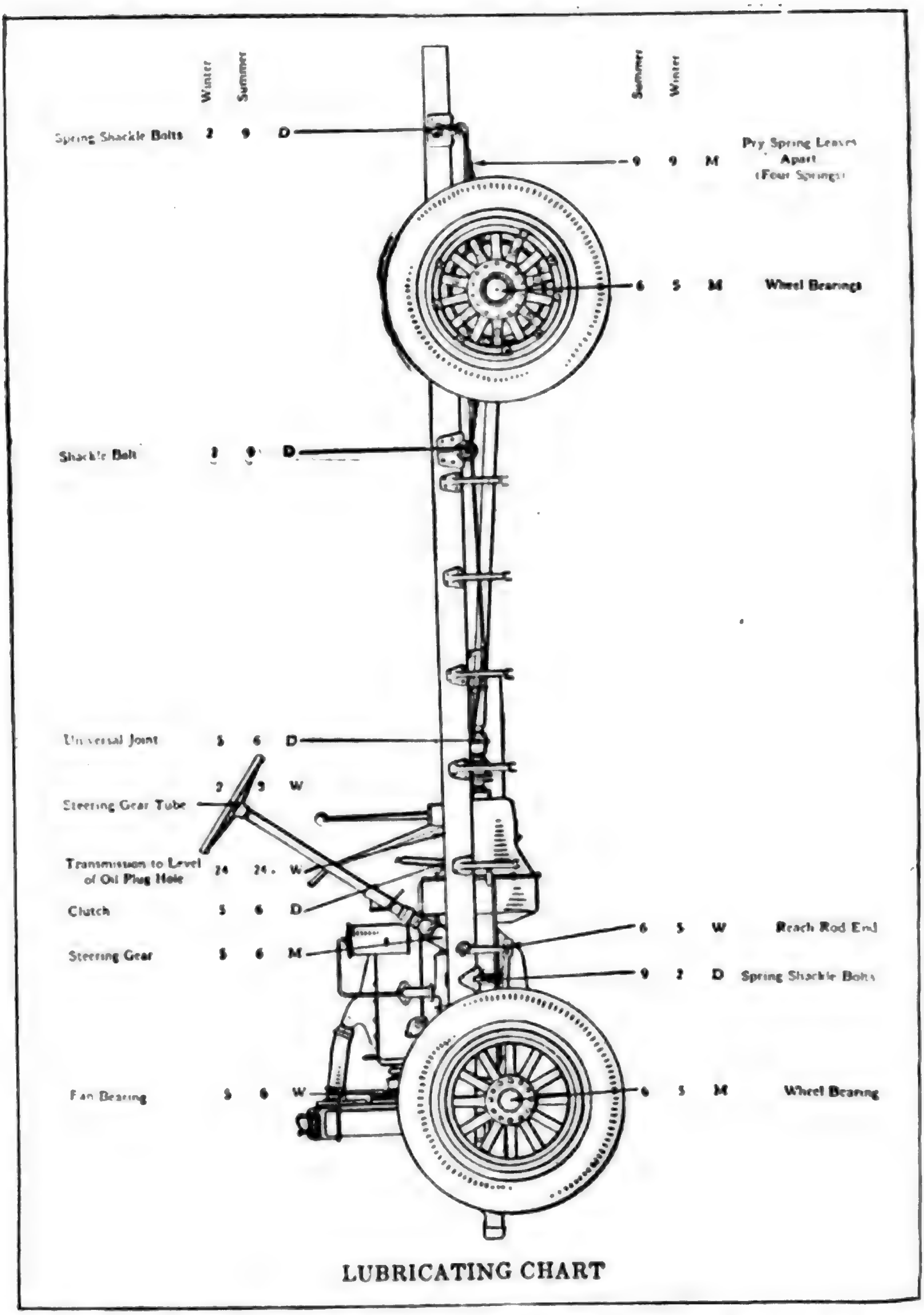

Winter
Summer
Spring Shackle Bolts 2 9 D
Summer
Winter
9 9 M Pry Spring Leaves Apart (Four Springs)
6 5 M Wheel Bearings
Shackle Bolt 2 9 D
Universal Joint 5 6 D
2 3 W
Steering Gear Tube
Transmission to Level of Oil Plug Hole 24 24 W
Clutch 5 6 D
Steering Gear 5 6 M
6 5 W Reach Rod End
9 2 D Spring Shackle Bolts
Fan Bearing 5 6 W
6 5 M Wheel Bearing
LUBRICATING CHART

Fig. 288.—Side Elevation of Commerce 1-Ton Capacity Truck, Showing Points Requiring Lubrication.

ENGINE

2-B. Summer, Oil Reservoir capacity 5 quarts. Oil Level to be brought to "Full" DAILY.

2-A. Winter, DAILY.

Five quarts of lubricating oil are carried in the bottom of the crankcase. The amount of oil is indicated by the position of the indicator hand on an oil level gauge located on the left-hand side of the engine oil pan, as shown at Fig. 290, A.

Every month or after about 1,000 miles running, the engine crankcase should be cleaned and the oil supply entirely renewed. With the type of splash lubrication used on this engine do not attempt to clean it with kerosene without removing the oil pan.

For this monthly cleaning drain the oil from the oil pan through the plug in the bottom. Fill the crankcase with about a quart of kerosene and run the engine about one minute at half throttle. Then drain the kerosene from the oil pan.

Remove oil pan from engine and thoroughly clean it out, removing all traces of kerosene. Replace and fill crankcase with five quarts of fresh lubricating oil.

Do not use waste or linty rags for cleaning, as they are liable to clog oil pump and cause the destruction of the engine.

WATER PUMP

The water pump grease cup shown at Fig. 290, B, should be filled weekly and should be screwed down one turn daily.

FAN BEARING

No. 5 weekly

Remove plug in hub of fan pulley shown at Fig. 290, C, and inject No. 5 grease weekly.

MAGNETO

No. 2 light weekly

Two drops only of a light, clean oil injected into the oil wells depicted at Fig. 290, D, every week or so will be sufficient. Two of these oil wells are located on the sides of the distributor housing, oiling the armature ball bearing, the distributor plain bearing, and the circuit breaker. The other oil well is located on

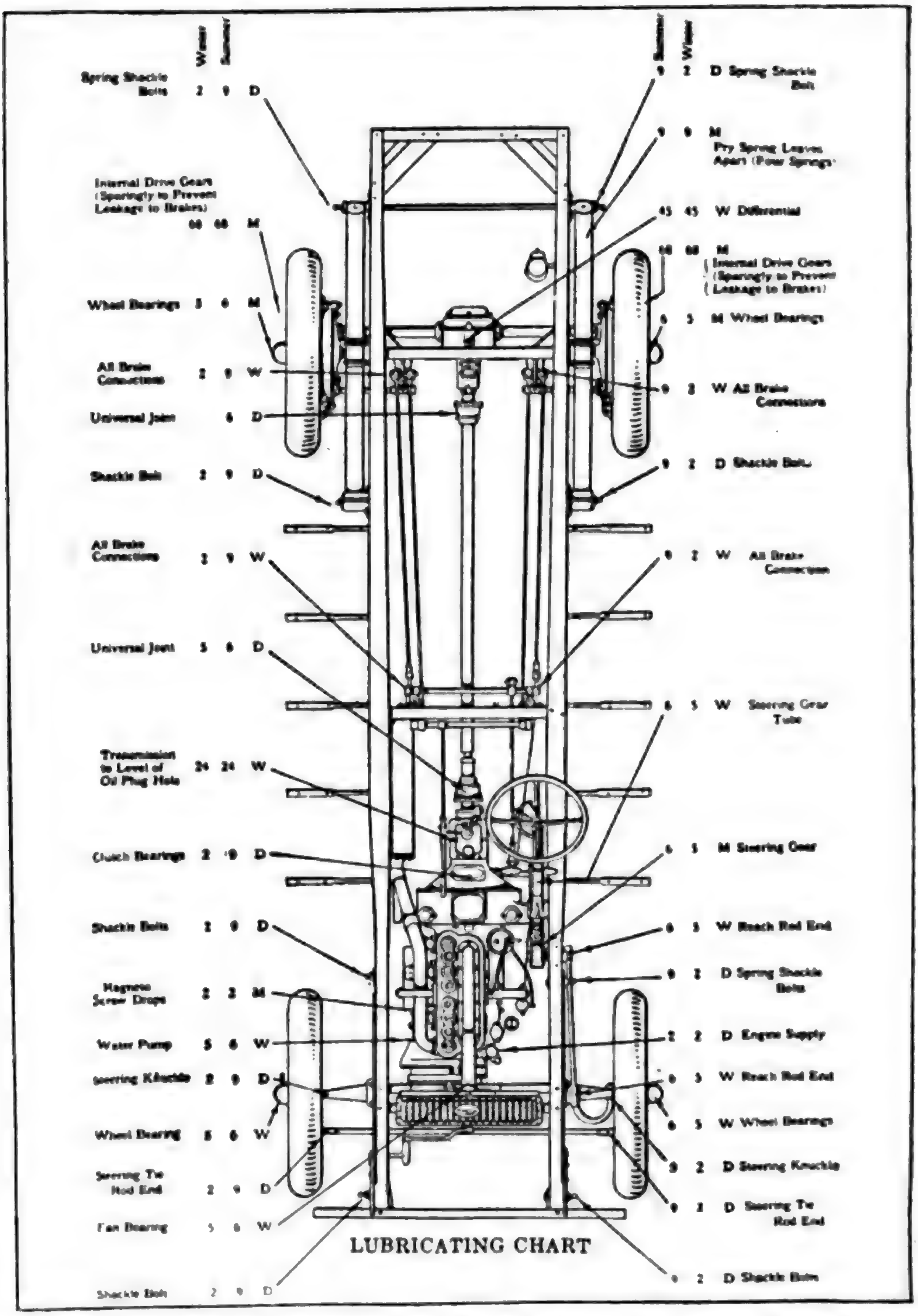

Winter
Summer
Spring Shackle Bolts 2 9 D
Internal Drive Gears (Sparingly to Prevent Leakage to Brakes) 60 60 M
Wheel Bearings 5 6 M
All Brake Connections 2 9 W
Universal Joint 6 D
Shackle Bolt 2 9 D
All Brake Connections 2 9 W
Universal Joint 5 6 D
Transmission to Level of Oil Plug Hole 24 24 W
Clutch Bearings 2 9 D
Shackle Bolts 2 9 D
Magneto Screw Drops 2 2 M
Water Pump 5 6 W
Steering Knuckle 2 9 D
Wheel Bearing 5 6 W
Steering Tie Rod End 2 9 D
Fan Bearing 5 6 W
Shackle Bolt 2 9 D
Summer
Winter
9 2 D Spring Shackle Bolt
9 9 M Pry Spring Leaves Apart (Paint Springs)
45 45 W Differential
60 60 M Internal Drive Gears (Sparingly to Prevent Leakage to Brakes)
6 5 M Wheel Bearings
9 2 W All Brake Connections
9 2 D Shackle Bolt
9 2 W All Brake Connections
6 5 W Steering Gear Tube
6 5 M Steering Gear
6 5 W Reach Rod End
9 2 D Spring Shackle Bolts
2 2 D Engine Supply
6 5 W Reach Rod End
6 5 W Wheel Bearings
9 2 D Steering Knuckle
9 2 D Steering Tie Rod End
9 2 D Shackle Bolts
LUBRICATING CHART

Fig. 289.—Plan View of Commerce 1-Ton Truck, Showing Points Needing Periodical Lubrication.

the extension of the end plate above the impulse starter, and lubricates the ball bearing on the end of the magneto.

CONTROL SET, CLUTCH AND GEARSET

No. 6 in summer } weekly
No. 5 in winter }

The grease cups should be filled on the pedal shaft bearings.

No. 2-A weekly

Also all foot and hand brake rod clevises, steering gear and foot pedal connections, throttle control rods and connections and all other working joints not provided with oil or grease cups should be lubricated with an oil can, using cylinder oil No. 2 light or 2-A medium. The lubrication of the clutch bearing is shown at Fig. 290, E; that of the change speed gear at Fig. 290, F.

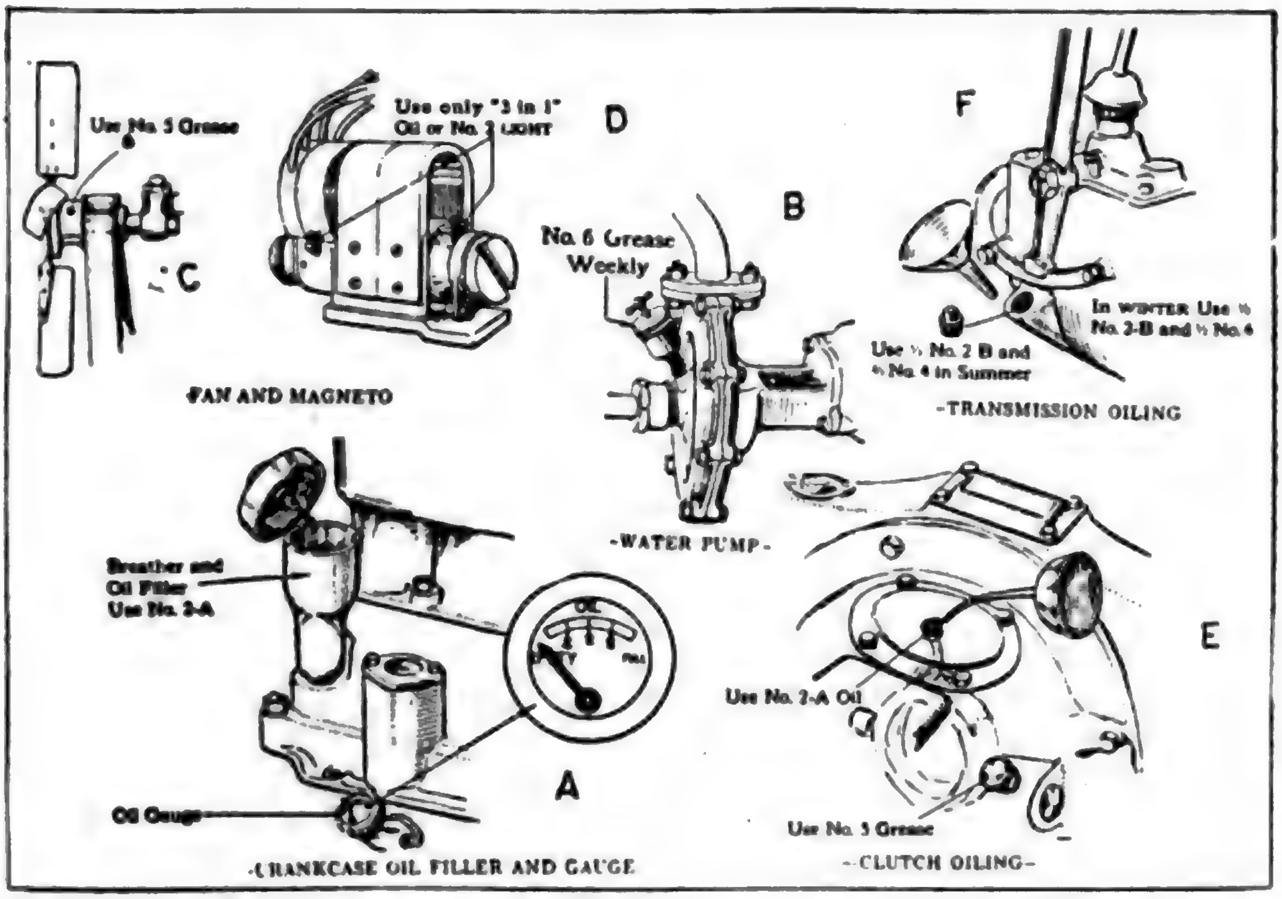

Use No. 5 Grease
C
Use only "3 in 1" Oil or No. 2 LIGHT
D
FAN AND MAGNETO
No. 6 Grease Weekly
B
-WATER PUMP-
F
In WINTER Use ½ No. 2-B and ½ No. 6
Use ½ No. 2 B and ½ No. 4 in Summer
-TRANSMISSION OILING
Breather and Oil Filler Use No. 2-A
Oil Gauge
A
-CRANKCASE OIL FILLER AND GAUGE
Use No. 2-A Oil
E
Use No. 5 Grease
-CLUTCH OILING-

Fig. 290.—Points on Power Plant of Commerce 1-Ton Truck Needing Oil.

STEERING GEAR

No. 6 in summer } weekly
No. 5 in winter }

To lubricate, remove a plug which is near the lower end of the steering column housing, as shown at Fig. 291, A, and inject lubricant freely. Also inject No. 2 light oil into ball spring oiler at top of steering column.

DRAG LINK

No. 6 weekly

The drag link connects the steering gear arm and the steering arm on the front axle. The connections are in the form of ball and socket joints which should be packed with grease weekly. The lubrication of axle end and steering linkage is clearly shown at Fig. 291, B. The spring shackle oilers are shown at Fig. 291, C.

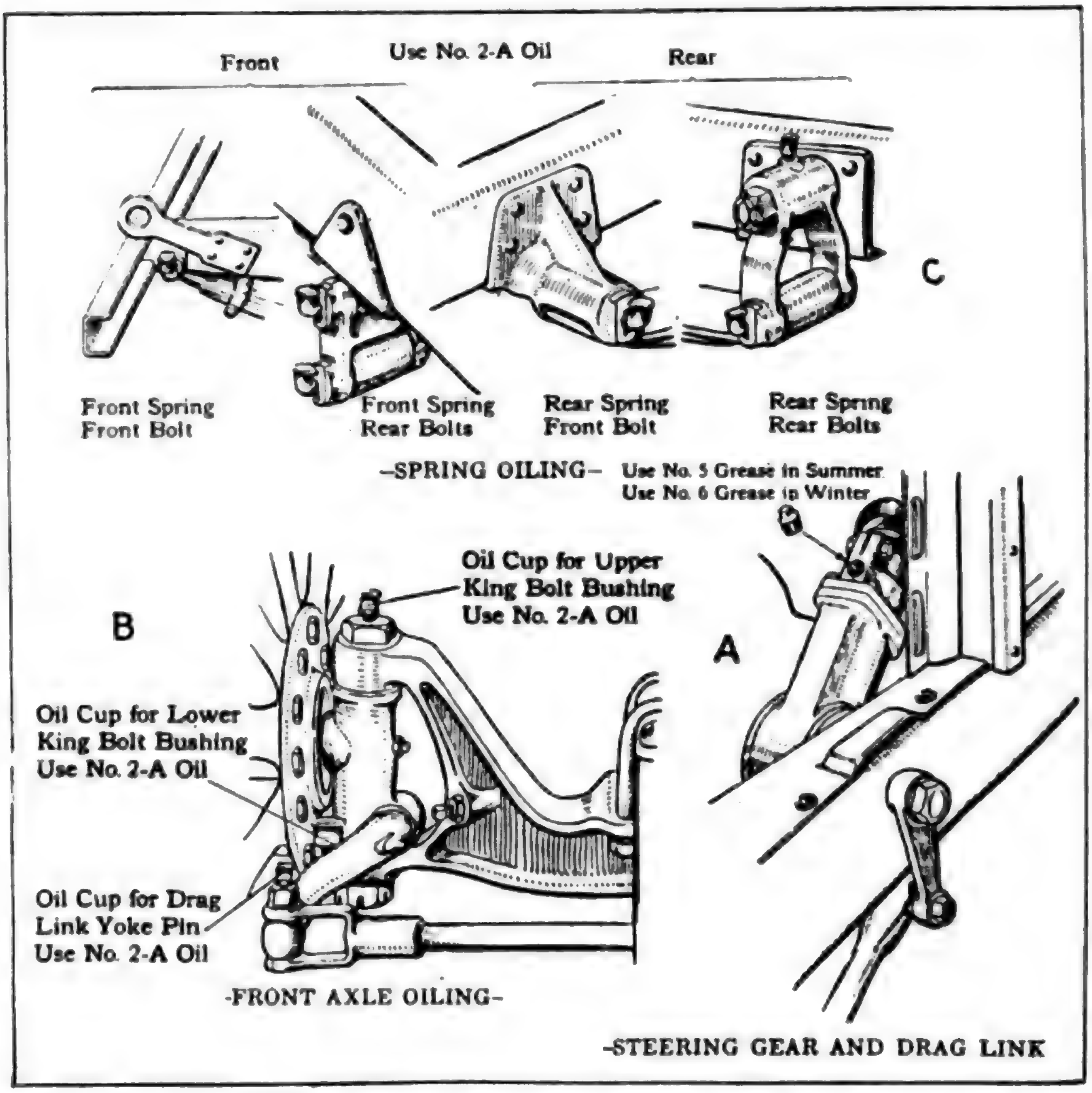

Front
Use No. 2-A Oil
Rear
C
Front Spring Front Bolt
Front Spring Rear Bolts
Rear Spring Front Bolt
Rear Spring Rear Bolts
-SPRING OILING-
Use No. 5 Grease in Summer
Use No. 6 Grease in Winter
B
Oil Cup for Upper King Bolt Bushing Use No. 2-A Oil
A
Oil Cup for Lower King Bolt Bushing Use No. 2-A Oil
Oil Cup for Drag Link Yoke Pin Use No. 2-A Oil
-FRONT AXLE OILING-
-STEERING GEAR AND DRAG LINK

Fig. 291.—Points on Chassis of Commerce 1-Ton Truck Needing Periodical Oiling.

BRAKE CROSS SHAFT BRACKETS

No. 2-A daily

The brake cross shaft brackets are located on either side of the third cross member, counting from the front, and should be lubricated with cylinder oil, No. 2-A, through oil holes provided.

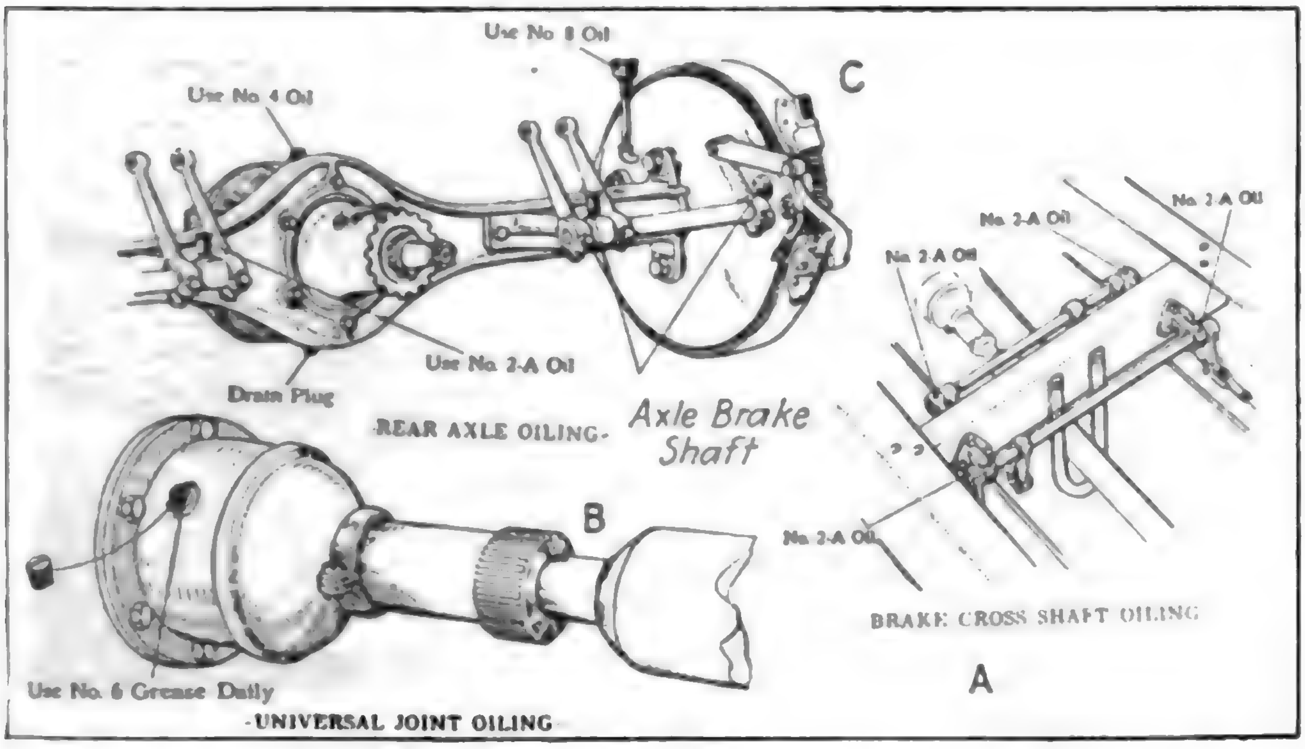

Use No 8 Oil
C
Use No 4 Oil
No. 2-A Oil
No. 2-A Oil
No. 2-A Oil
Use No. 2-A Oil
Drain Plug
REAR AXLE OILING
Axle Brake Shaft
B
No. 2-A Oil
BRAKE CROSS SHAFT OILING
A
Use No. 6 Grease Daily
UNIVERSAL JOINT OILING

Fig. 292.—Points in Driving System of Commerce 1-Ton Truck Needing Regular Oiling.

Clean the holes out before applying the oil. The brake cross shaft bearings are clearly shown at Fig. 292, A.

PROPELLER SHAFT UNIVERSAL JOINTS

No. 6 daily

Since both the propeller shaft universal joints are of the same construction, they are lubricated in the same manner. To lubricate them, remove the plugs at the top of each, shown at Fig. 292, B. Remove the old grease monthly with a grease gun, clean with kerosene and repack with fresh No. 6 cup grease.

REAR AXLE DIFFERENTIAL

⅗ of No. 4 and ⅖ of No. 5 in summer } every two weeks
¼ of No. 4 and ¾ of No. 5 in winter }

Remove the plug on top of the differential housing of the rear axle, as shown at Fig. 292, C, to inspect, and insert new lubricant. In order to clean, which should be done monthly, remove the rear plate on the differential housing. Drain all old lubricant through plug in bottom of differential housing and thoroughly clean with kerosene through opening on rear of housing. Fill to level with new lubricant after replacing rear differential housing cover.

REAR AXLE, INTERNAL DRIVE GEARS

50% of No. 6 } daily
50% of No. 8 }

To lubricate the internal gear pinion and gears of both wheels through grease cups provided between the brake carriers and the rear springs, and shown at Fig. 292, C.

JACK SHAFT BEARINGS

No. 6 in summer } daily
No. 5 in winter }

Fill and turn down each grease cup half way daily. These cups are at the flange connection between the brake carrier plate and jackshaft housing tube.

REAR AXLE BRAKE SHAFTS

No. 6 in summer } weekly
No. 5 in winter }

Fill grease cups located on rear axle brake shafts, as shown at Fig. 292, C, where they enter the brake carrier plate.

No. 2-A weekly

Oil cups are provided to oil brake shafts between brake levers on rear axle. Fill with cylinder oil weekly.

REAR WHEEL SPINDLE BEARINGS

No. 6 in summer } weekly
No. 5 in winter }

To lubricate the rear wheel spindle bearings fill the hubs after the hub caps have been removed. Replace hub caps securely after inserting fresh lubricant.

Springs.—Once every six months jack up the frame, remove the spring clips and pry the spring leaves apart. Lubricate between the leaves with graphite. Should the leaves be excessively rusted, it is well to dismantle the spring, remove the rust, and paint the leaves with graphite paint or white lead. The points to inspect in regard to spring fastenings are shown at Fig. 293; the shackle oiling is clearly outlined at Fig. 291, C.

Maintenance Routine.—It is essential for the proper care and maintenance of any truck that the following maintenance routine schedule be rigidly adhered to. Preparedness for emergencies can only be obtained by keeping the truck in excellent condition, and this necessitates proper adjustment at regular intervals of time.

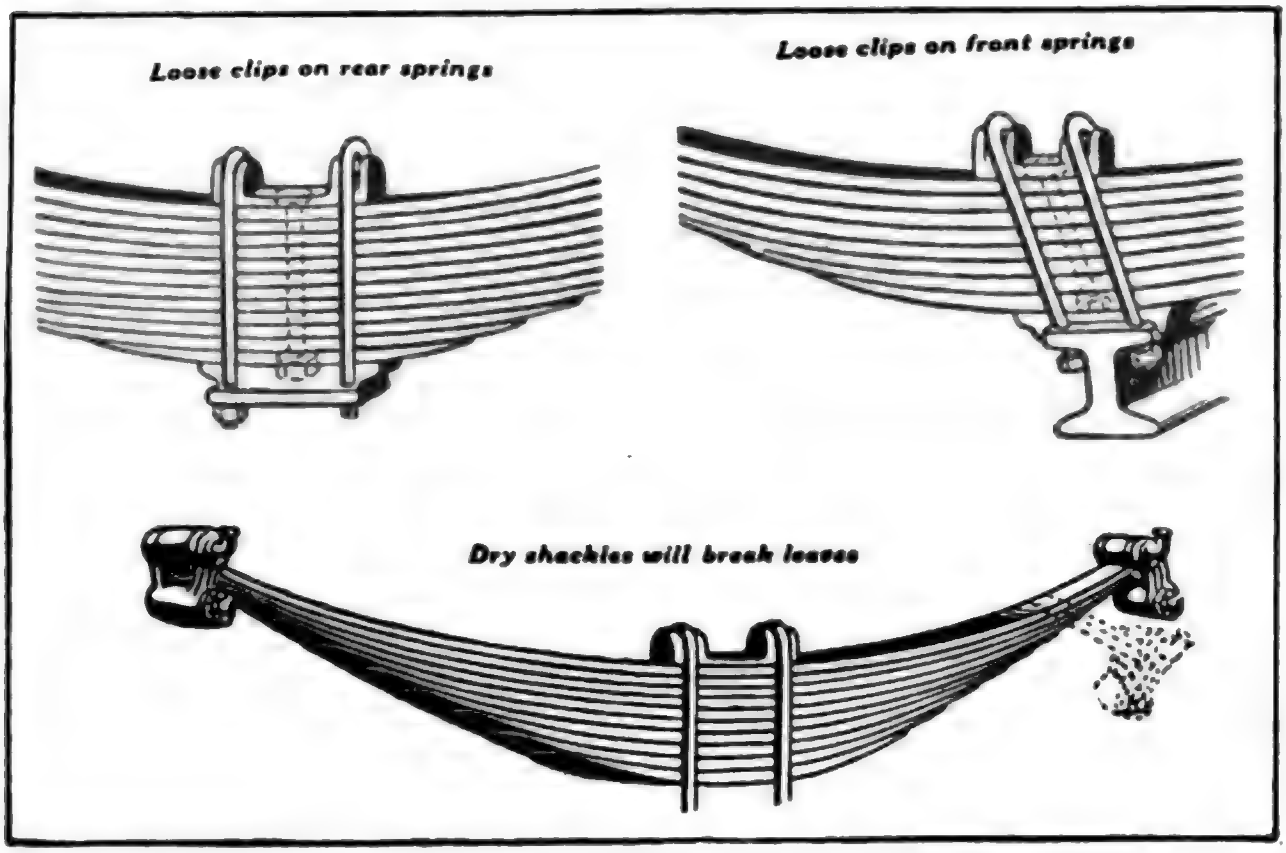

Loose clips on rear springs
Loose clips on front springs
Dry shackles will break leaves

Fig. 293.—Points to Inspect in Regard to Spring Fastenings.

Daily Maintenance Routine.—Engine: Examine all wiring terminals for tightness. Clean magneto externally. Note tension of fan belt. Inspect oil supply in engine crankcase. Inspect oil pump for performing its proper function. Inspect radiator water supply. Inspect loose connections for leaks. Inspect gasoline tanks for proper fuel supply. Inspect fuel pipe line and all connections for leaks.

Brakes: Inspect for undue wear or looseness and tighten if necessary. Inspect for proper operation.

General: Inspect and thoroughly clean all lamps. Fill and clean acetylene generator or fill kerosene lamps if electric lighting is not used. Inspect tires for air pressure, cuts or damage if of the pneumatic type. Tighten all loose bolts and nuts.

Weekly Maintenance Routine.—Engine: Inspect all wires for proper support and freedom from damage. Thoroughly clean engine externally. Inspect oil pump connections for oil leaks. Inspect all water connections for leaks. Inspect carburetor control connections. Do not attempt to alter carburetor adjustment unless this is shown to be necessary when the truck is in service.

Remove magneto distributor cover and clean with gasoline and clean cloth. Operate engine at low speed, and, with one wire at a time separated from spark plug, inspect the spark given for length and apparent hotness. Keep engine free from carbon; inject tablespoonful of kerosene into each cylinder, through petcock or spark plug holes. This should be injected when the motor is hot and allowed to stand over night. Remove, clean and adjust all spark plugs.

Brakes: Inspect and thoroughly clean and oil all brake connections. Adjust if necessary. Springs: Inspect center bolt of spring and spring clips for apparent tightness.

Wheels: Inspect front wheels for alignment with rear wheels. Inspect tires for undue damage and wear. Jack wheels up and inspect bearing adjustment. Inspect spindles and spindle bolts. Inspect tierod adjustment.

Clutch: Inspect entire clutch mechanism. Transmission: Clean and inspect all control connections.

Universal joints: Inspect universal joint for undue looseness and wear. Clean and refill universal joint with grease.

Differential: Inspect differential and propeller shaft bearing adjustment. Body and Equipment: Inspect body bolts, hood fasteners and all similar bolts for apparent tightness. Inspect tool equipment for completeness.

Monthly Maintenance Routine.—Engine: Determine if carbon is present in quantity in the engine. Examine and inspect engine for loose parts, leaks, noises. Clean oil pump screen. Grind valves if necessary.

Ignition: Clean magneto collector ring, polish and adjust breaker points. Inspect magneto cam for correct advance.

Clutch: Inspect clutch hub grease tube. Inspect clutch operation. Inspect clutch alignment.

Transmission: Clean externally and inspect for leaks, particularly the drain plug and the rear bearing.

Springs: Thoroughly inspect and clean spring shackle connections. Inspect springs to ascertain damage, if any.

Differential: Clean and inspect differential housing for oil leaks. Inspect brake arms and equalizers on differential housing.

Wheels: Remove hub caps and inspect for proper lubrication. Inspect condition of bearings. Universal Joint: Inspect universal joint ring and yokes. Inspect housing bolts inside joint housing. General: Inspect transmission arm bolts. Inspect front motor support bolts. Inspect oil pan and transmission bolts. Inspect steering gear for lost motion and lubrication. Inspect speedometer drive.

See that the shackles are free and do not bind with the nuts. Also keep them well lubricated, for dry shackles tend to permit the upper leaf—the only one fastened to the shackle—to bulge out of shape. This will break the leaf almost every time.

Spring Clips: These clips must be tight. The duty of the clips is to keep the various leaves together; if loose, they cannot do their duty; keep them tightened. If loose, the leaves are permitted to spring apart and they are bound to snap off at the center bolt. Loose clips also permit the leaves to shift forward or backward. This is especially true with the front spring. The shock is transmitted through the axle connection at the center bolt. If the clips are loose, the lower leaf will shift forward with the axle, while the upper leaf will remain steady with the load; consequently, the center bolt snaps off or gets badly twisted between leaves.

Center Bolt: The importance of the center bolt has already been mentioned. This bolt must be kept perfectly tight or the leaves will shift as shown. Should this get broken on account of any of the conditions previously described, remove at once and replace with a new bolt.

It is remarkable how many springs are broken because of lack of lubrication. The shackles must be kept well lubricated. The leaves should never be permitted to become dry.

In a nutshell—lubricate at shackles and between leaves; keep shackles free; do not permit shackles to bind by screwing nuts too tightly; see that the spring clips are tight; keep center bolts tight, replace if broken; go over bumps easily, dodge all possible; drive slowly over rough roads, and do not OVERLOAD.

The chassis plan of one of the smaller White truck models at Fig. 294 shows the points on that well-known chassis that de-

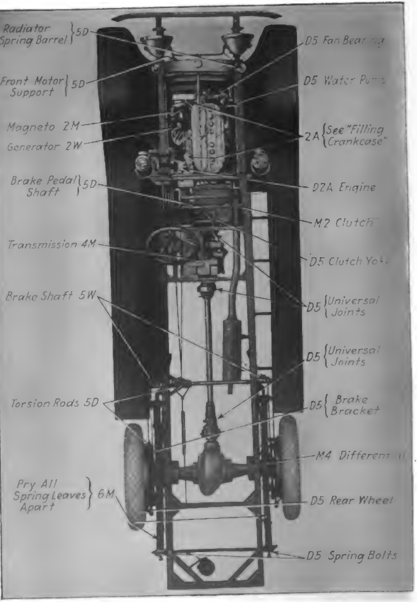

Radiator Spring Barrel 5D
Front Motor Support 5D
Magneto 2M
Generator 2W
Brake Pedal Shaft 5D
Transmission 4M
Brake Shaft 5W
Torsion Rods 5D
Pry All Spring Leaves Apart 6M
D5 Fan Bearing
D5 Water Pump
2A See "Filling Crankcase"
D2A Engine
M2 Clutch
D5 Clutch Yoke
D5 Universal Joints
D5 Universal Joints
D5 Brake Bracket
M4 Differential
D5 Rear Wheel
D5 Spring Bolts

Fig. 294.—Plan View of White Truck Chassis, Showing Points Needing Periodical Lubrication.

mand periodical attention. The detail illustrations at Fig. 295 show the various power plant points and the character of lubricant each should receive and how often. The same key letters apply for lubricants and periods of application as previously explained in connection with the Commerce one-ton truck outlined at Figs. 288 and 289.

The details at Fig. 296 show clearly the location of grease cups on running gear parts. Attention is directed to the grease-retaining bags used around rod ends that are usually neglected. This is a valuable feature and a refinement of detail that makes for reduced maintenance expense, because not only are the parts continually lubricated but they are kept free from the abrading effects of grit and dirt, a very important consideration.

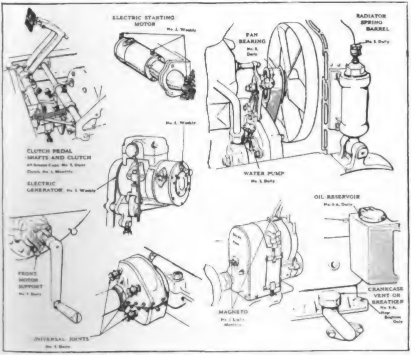

ELECTRIC STARTING MOTOR
No. 1, Weekly
FAN BEARING
No. 1, Daily
RADIATOR SPRING BARREL
No. 1, Daily
No. 1, Weekly
CLUTCH PEDAL SHAFTS AND CLUTCH
All Grease Cups No. 3, Daily
Clutch No. 1, Monthly
ELECTRIC GENERATOR No. 1, Weekly
WATER PUMP
No. 3, Daily
OIL RESERVOIR
No. 1-A, Daily
FRONT MOTOR SUPPORT
No. 1 Daily
CRANKCASE VENT OR BREATHER
No. 1-A
MAGNETO
UNIVERSAL JOINTS
No. 1 Daily

Fig. 295.—Points on White Truck Chassis Requiring Regular and Systematic Lubrication.

Motor Truck Control Systems.—The usual motor truck control system consists of various members, among which is a steering gear by which the vehicle is directed on its course. Spark and throttle control levers are placed convenient to the operator as on top of the steering column above the hand wheel, and are used to control the engine speed in connection with an accelerator that can be operated by the driver's foot. Normally, the hand throttle is intended only for starting purposes and for setting the minimum speed of engine rotation desired. All normal speed changes of the power plant are obtained by the accelerator pedal, which also works the throttle that regulates the gas supply that flows from the carburetor to the engine. An interlock is usually provided between the hand throttle lever and the accelerator pedal so that the latter is moved whenever the former is actuated, though the accelerator may be depressed without producing a corresponding movement of the hand throttle.

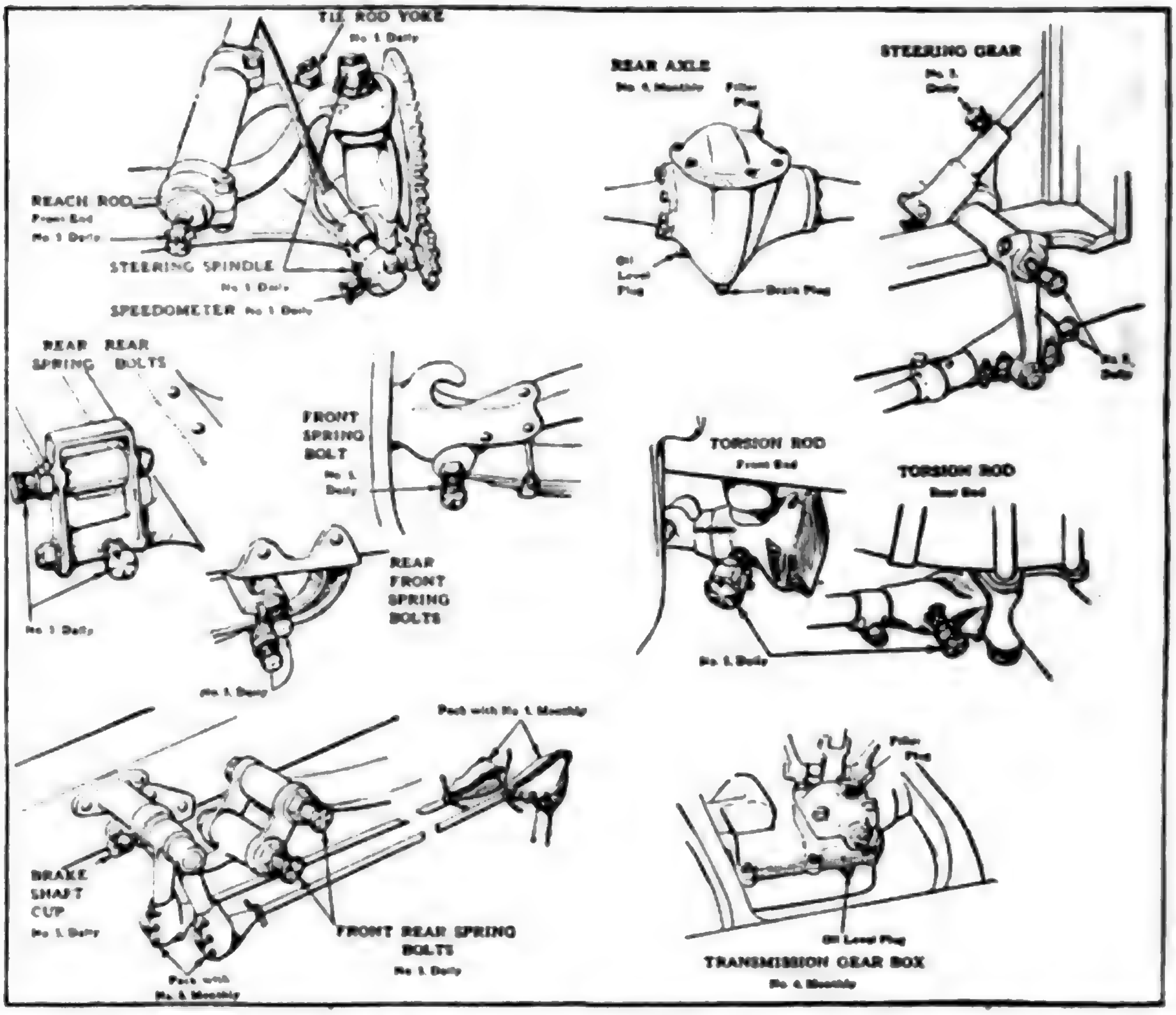

TIE ROD YOKE
No. 1 Daily
REACH ROD
Front End
No. 1 Daily
STEERING SPINDLE
No. 1 Daily
SPEEDOMETER No. 1 Daily
REAR AXLE
No. 4 Monthly
Filler Plug
Oil Level Plug
Drain Plug
STEERING GEAR
No. 1 Daily
No. 1 Daily
REAR SPRING
REAR BOLTS
No. 1 Daily
FRONT SPRING BOLT
No. 1 Daily
REAR FRONT SPRING BOLTS
No. 1 Daily
TORSION ROD
Front End
TORSION ROD
Rear End
No. 1 Daily
Pack with No. 4 Monthly
BRAKE SHAFT CUP
No. 1 Daily
Pack with No. 4 Monthly
FRONT REAR SPRING BOLTS
No. 1 Daily
Filler Plug
Oil Level Plug
TRANSMISSION GEAR BOX
No. 4 Monthly

Fig. 296.—Points on White Truck Running Gear Needing Regular Oiling.

Two other foot pedals are provided on all trucks using sliding gear transmission. One of these, usually at the driver's right and intended to be operated by the right foot, is employed to actuate the clutch and connect or disconnect the engine power from the transmission system at will. The other pedal, which is operated by the left foot of the driver, is used to apply the service brake. Two hand levers are fitted on practically all trucks. These may be located at the driver's right on the outside of the frame if the truck is a right-hand drive, at the driver's right in the center of the floor boards if the truck is a left-hand drive, or in forms where the steering wheel is placed on the left side of the chassis the gear control may be placed on the outside of the frame and at the driver's left hand. This latter is a rather unusual placing that is found on very few trucks.

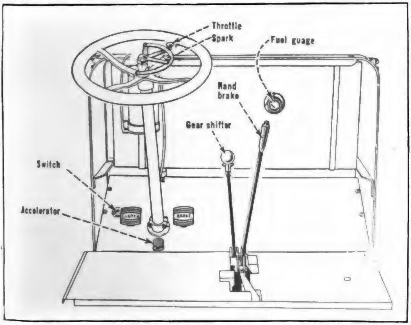


Fig. 297.—Control Members of I. H. C. Motor Truck.

The steering column and clutch and brake pedals may be at the right-hand side of the chassis or at the left-hand side, depending upon the opinion of the truck builder. Placing the steering wheel on the left side is the most consistent, and is the best practice when•one considers the road rules in vogue in this country, while right-hand placing is logical in European countries, such as England, where the road rules are opposite to those that prevail here. When two hand levers are employed, one is used for gear shifting, the other for applying an emergency brake.

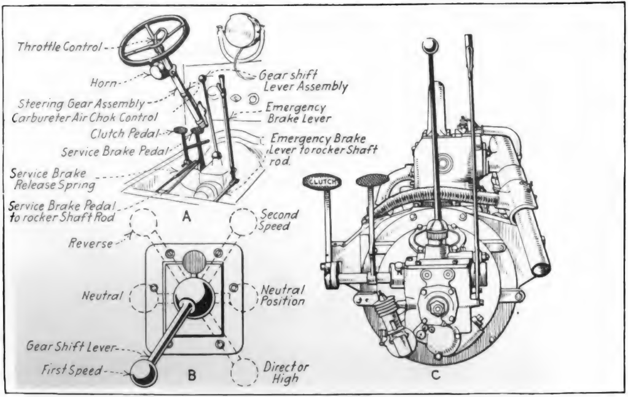

Throttle Control
Horn
Steering Gear Assembly
Carbureter Air Chok Control
Clutch Pedal
Service Brake Pedal
Service Brake Release Spring
Service Brake Pedal to rocker Shaft Rod
Gear shift Lever Assembly
Emergency Brake Lever
Emergency Brake Lever to rocker Shaft rod.
A
Reverse
Second Speed
Neutral
Neutral Position
Gear Shift Lever
First Speed
Direct or High
B
CLUTCH
C

Fig. 298.—Control System of Commerce 1-Ton Truck.

The control system of the International Harvester two-ton truck at Fig. 297 and that of the Commerce one-ton truck shown at Fig. 298 are typical of standard practice in which the steering wheel is placed on the left side and the gear shift and brake levers at the right of the driver and in the center of the chassis. The clutch pedal is always depressed whenever the gearshift lever is moved, as at Fig. 300, A, to either "engage" or "disengage" the change speed gearing, and the clutch is not reengaged until the desired gear ratio is fully meshed and it is desired to have the truck move forward or back under the engine power or when the change speed lever is in neutral position and none of the gears of the gear box are engaged. Normally, the foot brake has sufficient power to stop the truck, but in cases when an exceptionally quick stop is desired both hand and foot brakes are applied, as at Fig. 300, B.

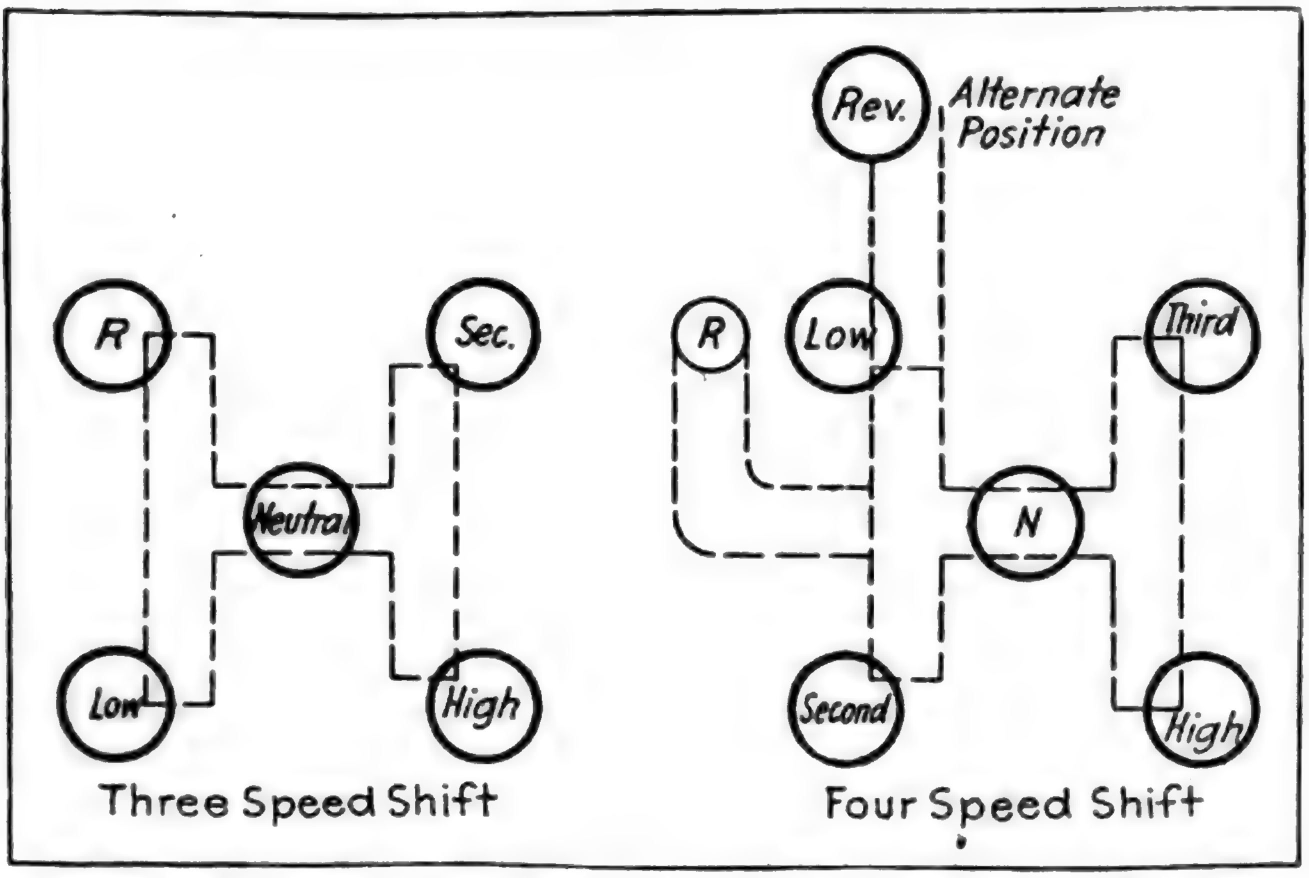


Fig. 299.—Change Speed Gear Lever Positions for Three and Four Speed Gear Shifts.

The position of the change speed lever to obtain various speed changes varies according to the type of transmission and the number of speeds provided. The two standard shift methods recommended by the S.A.E. are shown at Fig. 299. That at the left is for a three-speed shift, and is advised for use with either the cane shift or the H-slot systems. In one of these the lever is suspended on a ball and socket joint, as shown at Fig. 301, A, while in the other it is guided by slots in a quadrant, as shown at Fig. 301, B. The neutral position of the change speed lever is usually at a central point, as indicated. In the three-speed shift, moving the lever to the left and pulling back engages the low speed gears. Moving the lever to the left and pushing it forward engages the reverse gear. If the lever is moved from the neutral position to the right and then forward the second speed is engaged. If the lever is moved to the right, then pulled back, the high speed or direct drive is obtained.

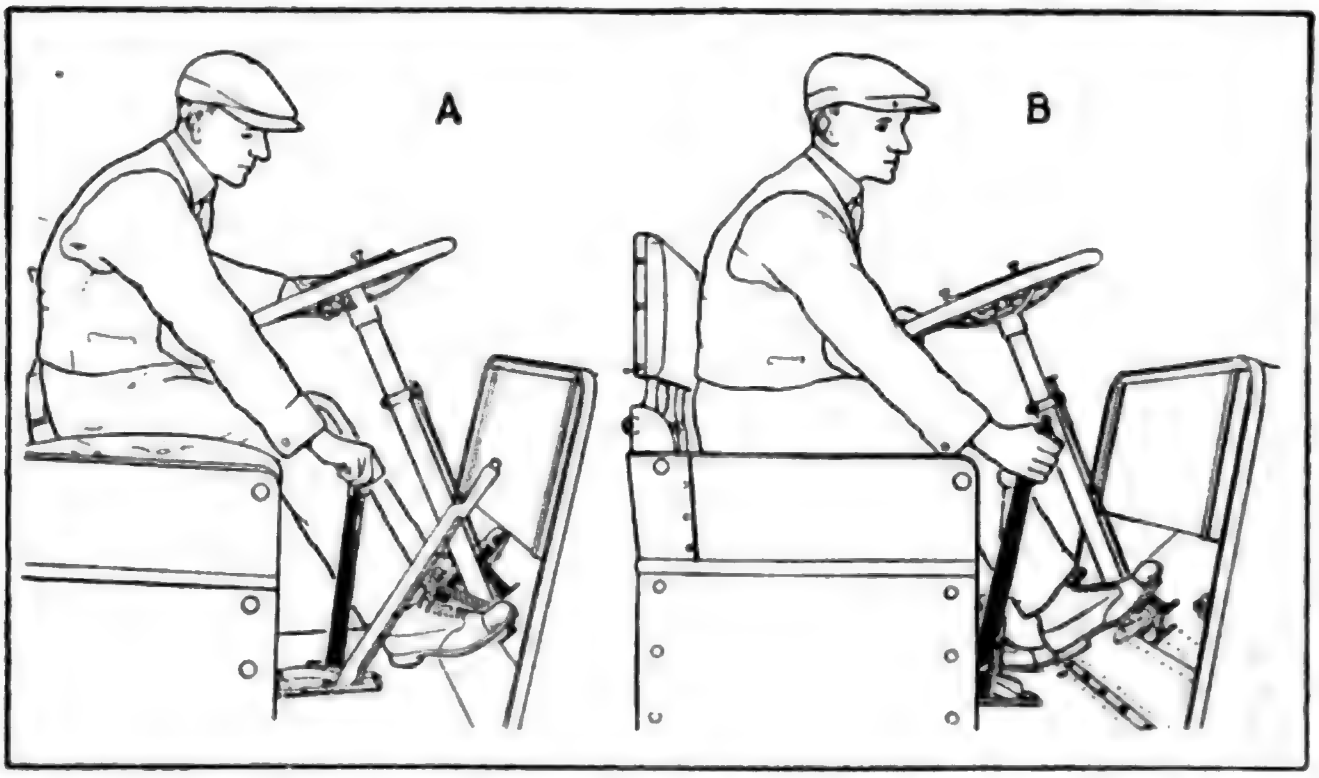


Fig. 300.—Always Depress Clutch Pedal Before Shifting Gears. A Shows Gear Shifting. B Outlines Brake Application.

With a four-speed gearshift a somewhat different arrangement is needed on account of the provision of an extra low speed. The reverse position depends on the construction of the gear box, but usually it is in one of the two positions indicated in the diagram at the right of Fig. 299. The design of a ball-jointed cane shift lever used with a three-speed gear box and the way the emergency brake lever is supported by the same casting is clearly shown at Fig. 301, A. When a four-speed gear box is used, the quadrant shift outlined at Fig. 301, B, is generally favored, because it is easier to select the reverse speed, which is provided with its own guiding channel in the quadrant, than would be the case with the system where speed changes are made without guiding slots. As a safeguard, the gearshift lever in a four-speed shift is invariably provided with a latch that must be lifted when it is desired to go into the reverse slot. This prevents the driver shifting into reverse without meaning to.

Typical Control Systems.—The control system of the Winther truck is clearly outlined at Fig. 302. In this the steering gear is placed on the right side of the frame, with the clutch and brake pedals disposed on either side of the steering column. The spark and throttle levers work on a quadrant attached to the steering column and are placed below the wheel rim. The emergency brake and change speed gear levers are attached to a quadrant at the center of the frame and are worked by the driver's left hand. All parts of this control system are clearly outlined and named in the drawing, so that further description is unnecessary.

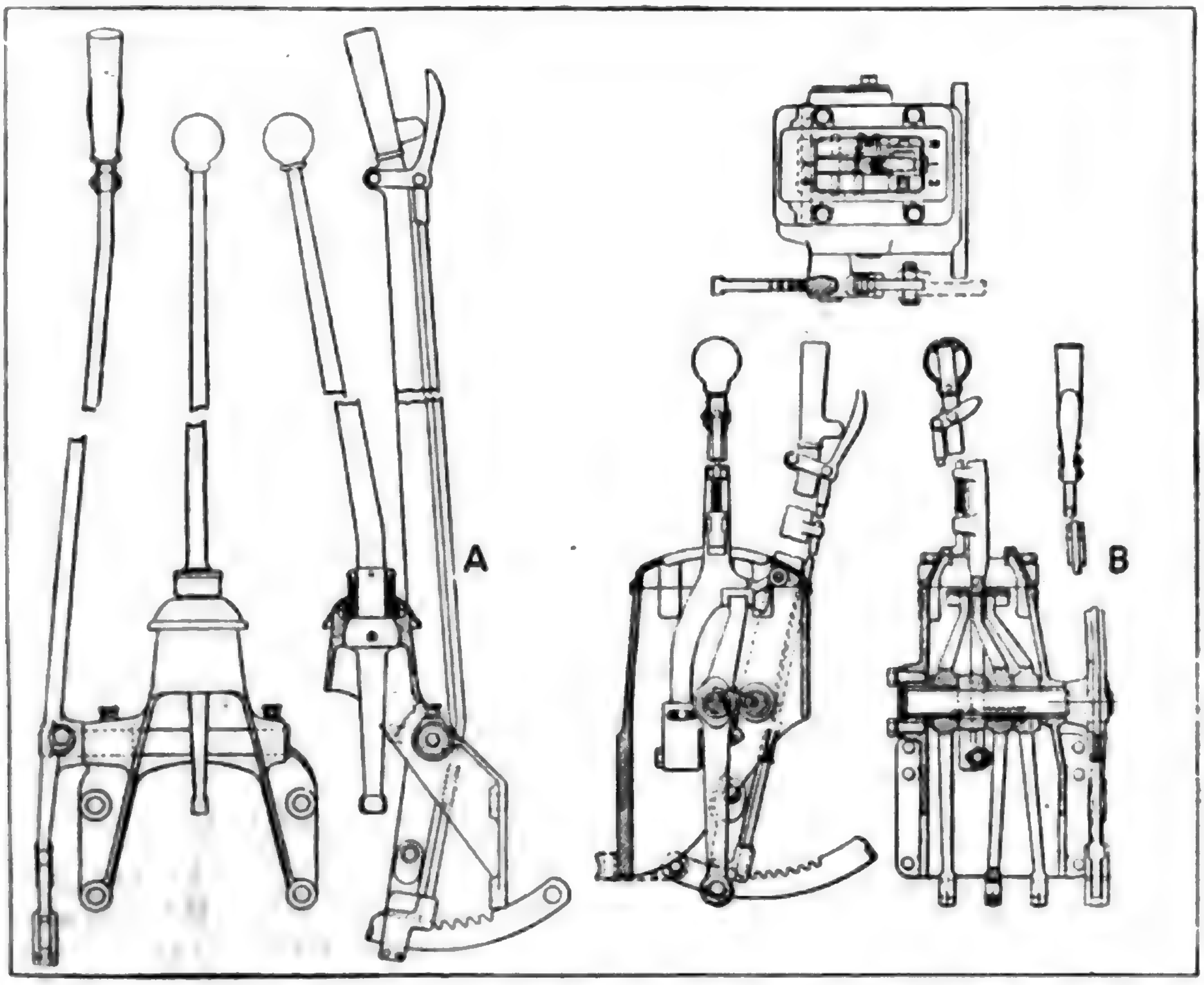


Fig. 301.—Cane Shift System at A and Quadrant Shift Method at B.

Nash Quad Control.—In the Nash-Quad the control elements are arranged in somewhat the same manner, except that the steering gear is carried at the left side of the frame. The gearshift is adapted for center control and both hand brake and gearshift levers are operated by the driver's right hand. The inset in Fig. 303 shows the quadrant employed and the position of the change speed shift lever to obtain the various ratios provided by the four-speed gear box.

F. W. D. Truck Control.—In the control system outlined at Fig. 304, which shows that used on the three-ton four-wheel drive truck, the application of side control levers are clearly outlined, and the placing of the steering gear at the right side of the truck is also shown. The driver is elevated more than is conventional practice and sits over the engine. The various parts of the control system are clearly depicted in the illustration, and the truck is controlled in the conventional manner.

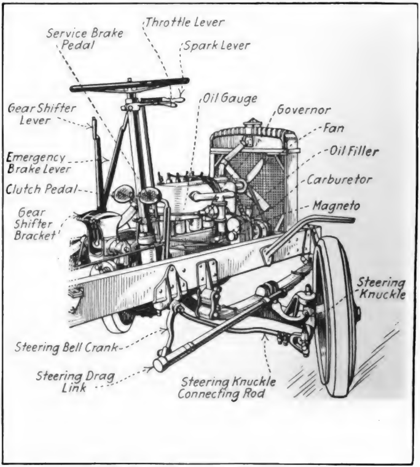

Throttle Lever
Service Brake Pedal
Spark Lever
Oil Gauge
Gear Shifter Lever
Governor
Fan
Oil Filler
Emergency Brake Lever
Carburetor
Clutch Pedal
Magneto
Gear Shifter Bracket
Steering Knuckle
Steering Bell Crank
Steering Drag Link
Steering Knuckle Connecting Rod

Fig. 302.—Control System of Winther Truck.

Pierce-Arrow Truck Control.—The control group of the Pierce-Arrow truck is shown at Fig. 305. In this the steering column is placed at the right side of the truck and outboard gearshift and brake levers are placed on the right side of the frame. Spark and throttle levers work on a quadrant under the steering wheel and at the left side of the steering column. As all parts are named on the illustration, the reader will have no difficulty in recognizing their functions.

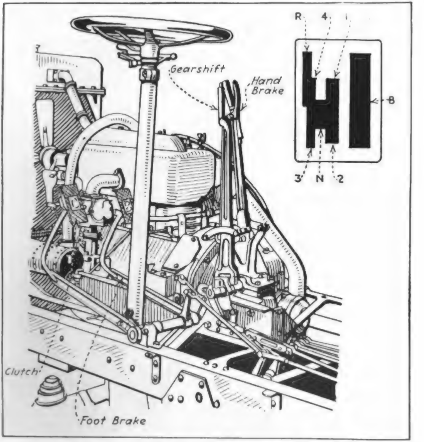


Fig. 303.—Control System of Nash Quad Truck.

Reo Speed Wagon.—The control system of the Reo speed wagon, which is shown at Fig. 306, is distinctive, as but one hand lever is used, this being the cane shift utilized for shifting gears. In this system the emergency brake effect is obtained

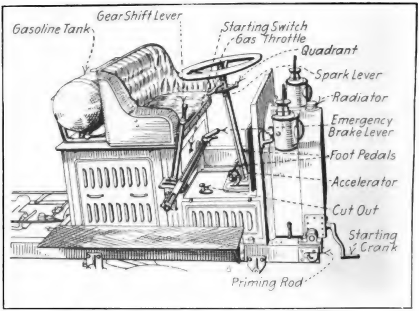

Gasoline Tank
Gear Shift Lever
Starting Switch
Gas Throttle
Quadrant
Spark Lever
Radiator
Emergency Brake Lever
Foot Pedals
Accelerator
Cut Out
Starting Crank
Priming Rod

Fig. 304.—Control System of F. W. D. Truck

by a foot pedal operated by the right foot, which may be locked in any desired position by a ratchet and latch working on a toothed segment. The service brake is applied by the same pedal that actuates the clutch. A certain movement releases the clutch, after which, if the pedal is depressed still further, the service brake is applied. It will be evident if one cannot

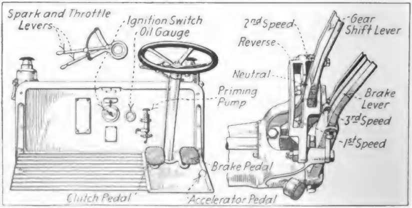

Spark and Throttle Levers
Ignition Switch
Oil Gauge
2nd Speed
Reverse
Gear Shift Lever
Neutral
Priming Pump
Brake Lever
3rd Speed
1st Speed
Brake Pedal
Clutch Pedal
Accelerator Pedal

Fig. 305.—Control System of Pierce-Arrow Truck.

apply the service brake without first releasing the clutch. The emergency brake, however, may be applied independently of the clutch pedal. The positions of the gearshift lever to obtain the different gear ratios are clearly outlined in the illustration. As an electric starting system is provided on this truck, a special foot-operated plunger is used to throw the starting switch in action. Its location is just forward of the change speed lever.

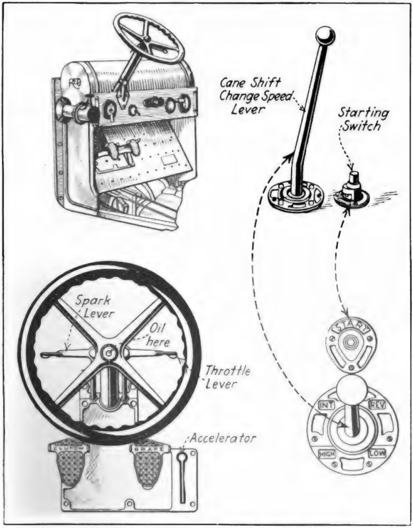

REO
Cane Shift
Change Speed
Lever
Starting
Switch
Spark
Lever
Oil
here
Throttle
Lever
Accelerator
CLUTCH
BRAKE
START
INT
REV
HIGH
LOW

Fig. 306.—Control System Parts of the Reo Speed Wagon.

The spark and throttle levers are attached to the steering column, the gas control being at the right side and the spark advance lever at the left.

White Truck Systems.—Some models of the White truck have the unconventional gearshifting systems outlined at Fig. 307. The steering column is placed at the left side of the chassis, with spark and throttle levers carried at the top of the steering post above the wheel. The hand brake lever is placed outboard on the left side of the frame, while the gearshift lever is located for center control and is actuated by the driver's right hand. The various positions of the lever to secure the four forward speeds and the one reverse are clearly shown in the diagram at the right of the illustration. As the shift is unusual, instructions for handling the lever follow.

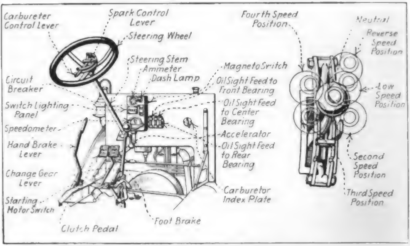

Carbureter Control Lever
Spark Control Lever
Steering Wheel
Steering Stem
Ammeter
Dash Lamp
Circuit Breaker
Switch Lighting Panel
Speedometer
Hand Brake Lever
Change Gear Lever
Starting Motor Switch
Clutch Pedal
Foot Brake
Magneto Sritch
Oil Sight Feed to Front Bearing
Oil Sight Feed to Center Bearing
Accelerator
Oil Sight Feed to Rear Bearing
Carburetor Index Plate
Fourth Speed Position
Neutral
Reverse Speed Position
Low Speed Position
Second Speed Position
Third Speed Position

Fig. 307.—Control System of White Trucks.

Handling White Gearshift Lever.—Grasp the handle of the change-gear lever lightly and move it sideways, which indicates neutral position, and then backward and forward through the different speed positions until you have become thoroughly familiar with its movements (engine not running). If you grip the lever hard, the muscles of the wrist become rigid and you lose the flexibility necessary for proper shifting of gears. In practicing gear shifting without the engine running, press downward with the left foot on the clutch pedal before attempting to move the lever, that you may acquire the habit. Never force he lever if the gears do not engage at once, but with the lever n neutral engage the clutch for a moment if the engine is running and then disengage it by depressing the clutch pedal. This will rotate the gears slightly and permit them to engage. Repeat if they do not engage readily on the first or second trials.

Gearshift Lever Positions.—The gearshift lever is moved into the following positions, which are plainly shown at Fig. 307, in order to make the necessary gear engagements in the transmission. The illustration of the quadrant on this page shows where the lever ought to be for the different speeds.

Neutral—Central position, and the only place where the lever may be rocked from side to side.

Low or First Speed—Depress the button on top of the lever, move the lever to the right, and push forward to the first notch.

Second Speed—Keep the lever to the right, and pull straight back as far as possible.

Direct or Third Speed—Push the lever forward one notch into neutral, move the lever to the left and pull back.

High or Fourth Speed—Keep the lever to the left, and push straight forward as far as possible.

Reverse—From neutral, move the lever to the right, push forward through low, and continue forward as far as possible.

Ford Model T Truck Control Distinctive.—The most unusual of all truck or car control systems is that used on the Ford Model T truck, which is the same as that used in the touring car as shown at Fig. 308. As several millions of these cars have been sold to date, and the present output of the factory is several thousand cars daily, many of which are used for utility purposes, it is evident that it is important to describe the control system of what is rightfully called the "universal" car.

The control system of this car is extremely simple and yet it is different from that of any other automobile. The gearset, which has been previously described, is a planetary type which gives two forward speeds and a reverse motion. The conventional form of steering wheel is used to control the direction of car travel, and spark and throttle levers are mounted on the steering column beneath the wheel to control the speed of the power plant. It is in the method of obtaining the various speed ratios that the control system is distinctive. As will be seen by referring to Fig. 308, three pedals and a hand lever are provided on the left side of the car. The pedal on the extreme left is used to control the high- and low-speed clutches and is marked "C." That next to it, which is marked "R," is used to constrict the reverse band of the transmission and obtain reverse motion The pedal at the right, which is provided with a letter "B" cast on its surface, is used to apply the foot brake.

The hand lever engages the high-speed or direct-drive clutch when thrown forward and when pulled back it actuates the emergency brake. An interlocking connection is provided so the emergency brake cannot be applied without releasing the direct-drive clutch. The lever may be set in a neutral position and the clutch will be released without applying the brake when it is approximately vertical. When the high speed is in and the hand lever is thrown way forward the high-speed clutch may be released by a light pressure on pedal "C" and a further movement of this pedal will apply the low speed. Thus one pedal gives control of both high and low speeds forward and the clutch can be released in exactly the same manner as that of a sliding-gear car when it is desired to slow up, such as for turning a corner, descending a hill or passing another vehicle.

Before starting the car the hand lever must be in a vertical position, this releasing the clutch and applying the emergency brakes. To start the car, after the engine has been started in the usual manner, the foot is placed on the clutch pedal to keep it in a neutral position, while the hand lever is thrown as far forward as it will go. The engine is then accelerated and the clutch pedal is pushed forward until the slow-speed band tightens around the drum of the transmission and the car gathers headway on the lower ratio. After it has attained a certain momentum, the clutch pedal is allowed to drop back gradually into the high-speed position. The foot may then be removed until such times that the clutch must be disconnected. Before applying the foot brake, which is done by pressing with the right foot upon the pedal marked "B," the clutch pedal should be put in neutral position with the left foot.

To reverse the car, it must first be brought to a standstill. The engine is kept running and the clutch is disengaged with the hand lever, which is placed in the neutral position but not pulled far enough back to apply the emergency brake. The reverse pedal marked "R" is then pushed forward with the left foot, leaving the right one free to use on the brake pedal if needed. To stop the car, the throttle is closed so that the engine will not race; the high speed is released by pressing the clutch pedal forward into its neutral position and applying the foot brake slowly, but firmly, until the forward motion of the car is arrested. It is imperative that the foot be retained on the clutch pedal until the hand lever is pulled back to its neutral position. The placing of the spark and throttle levers is clearly shown in the inset in the lower right-hand corner of the cut, both levers being pulled back to accelerate the motor and pushed forward to slow it down. The same rules given for the manipulation of the spark and throttle levers apply just as well to this make as to other trucks.

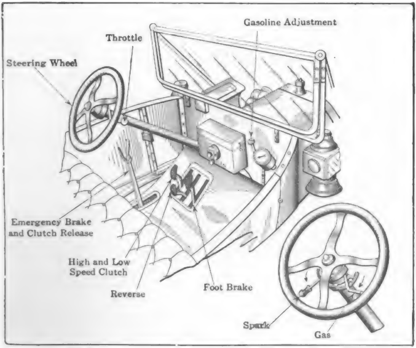

Gasoline Adjustment
Throttle
Steering Wheel
Emergency Brake and Clutch Release
High and Low Speed Clutch
Reverse
Foot Brake
Spark
Gas

Fig. 308.—Outlining Distinctive Control System of the Ford Model T Truck, which Employs Two-Speed and Reverse Planetary Gearing. Location of Spark and Throttle Levers Clearly Shown in Inset.

A point necessary to consider when operating a planetary transmission is that the slow and reverse speed must be applied gradually and that the engine be speeded up pretty well before either reverse or slow-speed bands are tightened. After the car has attained a certain degree of momentum on the low speed the pedal should be eased into the high-speed position gradually in order to avoid the sudden jump which always obtains when changing from the low to the high speed of a two-speed car. This jump is caused by a sudden acceleration due to the higher ratio provided by the direct-drive position, which is much higher than the maximum speed permitted by the slow-speed gears.

To Start the Mack Truck Engine

1. Take position in driver's seat behind steering wheel.

2. At the right of your knee are two levers. The left hand is the speed control or "Shifting Lever." Make sure that this is in neutral; that is, in a vertical position, and that it swings freely right and left.

3. The right hand is the emergency brake lever and should be set by pulling towards seat. Do not drag the pawl over the teeth of the ratchet, but hold the release against the lever in setting as in releasing the brakes.

4. On the steering wheel are two levers—the longer for the gas throttle valve and the shorter for the ignition spark. Advance the throttle lever one-third way on quadrant.

5. Set the spark lever at full retard.

6. Leave the driver's seat and take position in front of starting crank.

7. Close carburetor choker valve by pulling wire at the left of starting crank.

8. Spin the engine four or five revolutions with choker valve closed so that cylinders may fill with gas.

9. Close ignition switch.

10. Grasp starting crank in palm of left hand, engage and pull up one-quarter turn.

11. When engine starts, close choker valve. If above procedure fails to start engine, grasp starting crank with right hand and spin the engine four or five revolutions with choker valve closed. When spinning engine with ignition switch on, be sure that spark lever on wheel is fully retarded.

12. When engine is running regularly retard throttle lever until engine runs at slow speed.

13. Set spark lever at full advance.

NOTE: If motor starts hard or runs irregularly, do not attempt carburetor or other adjustments until motor has warmed up to its normal temperature.

Detailed Instructions for Mack Truck Operation.—To start the truck with engine running properly on retarded throttle and advanced spark take position in driver's seat behind steering wheel.

1. Release the emergency brake lever as far as it will go towards the dash.

At the base of the steering column are three pedals, two large and one small. The left-hand large pedal when pushed forward disengages the clutch. The right-hand large pedal when pushed forward applies the service brake. The small pedal is the "Accelerator," which connects with the gas throttle, independent of the throttle lever on the steering wheel.

2. Disengage the clutch with left foot.

3. Move the gear "Shifting Lever" into low or first-speed position with the clutch disengaged.

4. With the right foot press down lightly on the small "Accelerator" pedal, and with the motor turning over at a fairly good speed—

5. Engage clutch carefully. Do not remove left foot from clutch pedal but let the clutch in gradually to prevent truck from "jumping."

6. Press down gradually on accelerator pedal as you engage the clutch. First, to prevent motor from "stalling," and, second, to give the truck sufficient momentum to shift to the next higher speed.

7. Disengage clutch with left foot.

8. Allow accelerator pedal to return to normal position.

9. Move the gear "Shifting Lever" into intermediate or second speed with the clutch disengaged.

10. With the right foot press down on the "accelerator" pedal, and with the motor turning over at good speed—

11. Engage the clutch carefully, pressing down the "accelerator" pedal sufficiently to give the truck good momentum for the shift to the next higher speed.

12. Disengage clutch with left foot.

13. Allow the "Accelerator" pedal to return to normal position.

14. Move the gear "Shifting Lever" into high or third, with the clutch disengaged.

15. Engage clutch carefully.

16. Control the speed of the truck by means of the "Accelerator" pedal.

17. Run the truck with spark fully advanced. Retard the spark only when engine knocks on hills or in heavy going. Advance the spark again as soon as conditions are favorable.

To Change from High to Low Speeds

1. If retarding the spark does not overcome engine knocks and laboring—
2. Disengage clutch with left foot. Push pedal clear down.
3. Allow "Accelerator" pedal to return to normal position.
4. Move the gear "Shifting Lever" into next lower speed.
5. Engage clutch carefully, pressing down "Accelerator" pedal to maintain momentum.

NOTE: You should study the speed of the truck on each of its forward speeds and move the gear shifting lever at a truck speed which corresponds with the forward speed which you are about to engage. When shifting up, move quickly so that truck will not lose momentum.

When shifting down, release clutch, then hesitate an instant so that truck may lose a little momentum before engaging lower gear. It is easier to change speeds with motor throttled down than when it is racing.

To Stop the Truck

1. Disengage clutch with left foot.
2. Allow "Accelerator" pedal to return to normal position.
3. Press down service brake pedal gradually with right foot.

NOTE: If you push down too hard on the brake pedal it will lock the rear wheels. If ground is slippery truck will skid. If ground is dry tires will be damaged. It is much better to pick out the point at which you wish to stop in advance, and coast up to it slowly with clutch disengaged than it is to drive up at full speed and slam on the brakes in the last few feet. If an emergency stop is necessary, use the emergency brake in addition to the foot brake.

When Truck Has Come to Stop

1. Move gear "Shifting Lever" to neutral position.

2. Set the emergency brake.
3. Engage clutch.

To Stop the Motor

1. Advance the throttle lever on steering wheel about one-third way on quadrant.
2. Open the ignition switch.

To Reverse the Truck

Never attempt to reverse the truck until it has been brought to a stop. Stripped gears may result.

1. Disengage clutch with left foot.
2. Move gear "Shifting Lever" into reverse speed with the clutch disengaged.
3. Press down lightly on the small "Accelerator" pedal.
4. Engage clutch carefully.
5. Back your truck very carefully. Do not back your rear wheels into soft ground. Do not back the rear end of your frame over a loading platform. Do not back any part of your truck against a curb, loading platform or building.

General Operation of Packard Trucks

To prepare the truck for service: Fill the radiator with clean water. Fill the gasoline tank. Turn on the gasoline. Be sure that the lubricating oil in the motor crankcase is up to the overflow level. Be sure that all parts requiring lubrication are supplied with the proper lubricant. The truck is shipped from the factory with a supply of oil in all parts.

Preliminary to starting the motor put the change speed lever in neutral position. (See Fig. 309.) Set the hand brake. Open the throttle until the accelerator drops slightly. Move the auxiliary air valve adjusting lever on control board toward "Gas." About half way in warm weather; all the way in cold weather. Both primary and secondary air intakes may be choked by pulling out the knob under left side of front bumper. When truck is equipped with electric starter use the button in the center of the control board. Be sure that the dash indicator shows pressure in the fuel tank. Initial pressure may be obtained by using the hand pump.

To start the motor: By cranking—Fully retard spark lever on control board. (See Figs. 309 and 310.) Turn the ignition switch to B. Engage the starting crank and give it several rapid turns. On the magneto—In case the battery should be run down, the motor may be started on the magneto. Set spark lever in mid position. The throttle should be open until accelerator pedal drops slightly as for other methods of starting. Turn the ignition switch to M. Crank the motor by spinning rapidly. With electric starter—Turn the ignition switch to M. Set spark lever in mid position. Crank motor by pressing down on heel button. Release button as soon as motor starts firing.

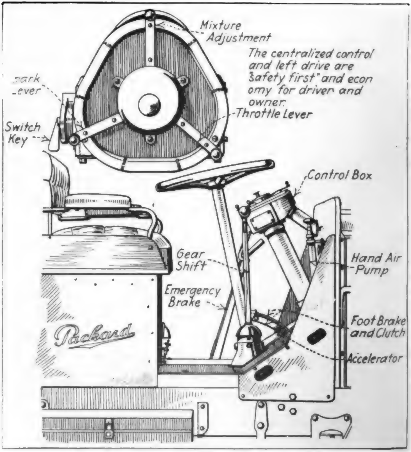

Mixture Adjustment
The centralized control and left drive are "safety first" and economy for driver and owner.
Spark Lever
Switch Key
Throttle Lever
Control Box
Gear Shift
Emergency Brake
Hand Air Pump
Foot Brake and Clutch
Accelerator
Packard

Fig. 309.—Control System of Packard Truck.

After the Motor Starts.—Turn the ignition switch to M. It will be in that position if the motor has been started on the magneto. Move the auxiliary air valve lever on the control board toward "Air" and set it at the point at which the motor runs best. An experienced operator may obtain a still finer adjustment by resetting this lever with the throttle closed. Close the throttle until the motor runs slowly.

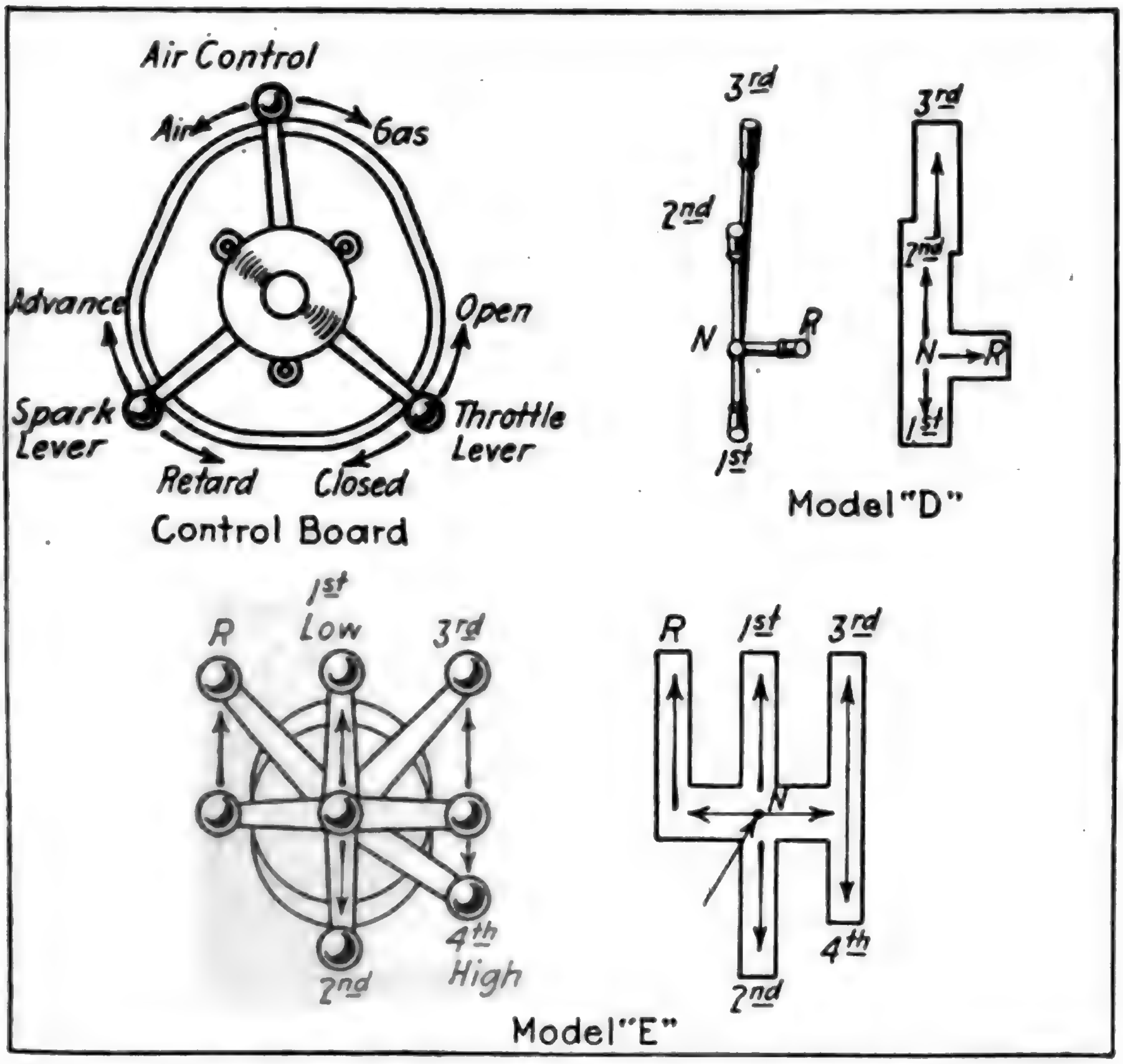

Air Control
Air
Gas
Advance
Open
Spark Lever
Throttle Lever
Retard
Closed
Control Board
3rd
2nd
N
R
1st
3rd
2nd
N
R
1st
Model "D"
1st Low
R
3rd
4th High
2nd
R
1st
3rd
N
4th
2nd
Model "E"

Fig. 310.—Packard Control System Details.

To Operate the Truck.—Release the hand brake. This should not be done until driver is seated in the truck. The clutch pedal must be depressed before attempting to shift gears. Always start the truck at its lowest gear ratio and allow it to gain its maximum speed by running at each succeeding gear ratio. All model D trucks have transmissions giving three speeds forward, and all model E trucks have transmissions giving four speeds forward. Always accelerate the motor slightly before engaging the clutch. After gears are shifted engage clutch slowly until it starts to grip and hold and truck picks up speed, then remove foot from pedal. When stopping truck throw out clutch pedal and then be sure to put change speed lever in neutral position, pull up hand brake lever and engage clutch.

To Reverse.—To reverse the "D" model truck having a three-speed transmission first push down the change speed lever reverse button before attempting to put the lever into position. On "E" model truck it is necessary to raise the latch which is at the upper end of the shifter lever. For movement of lever see diagrams at Fig. 310. It is important on heavy pulls to change to lower gear, instead of retarding spark. When starting uphill or on heavy pulls shift to a low gear immediately instead of waiting until the truck has lost its momentum. Keep spark advanced as fully as possible without causing the motor to knock. Keep air control lever as far as possible toward "Air" at left side of sector. When motor pops in carburetor move the lever one or two notches back toward "Gas."

To Stop the Motor.—Turn switch to "O" position and, while the motor is still turning from its own momentum, open the hand throttle about one-third and turn auxiliary air valve adjusting lever on control board toward "Gas." This provides a rich mixture, desirable for starting the motor the next time. The lever should not be moved as far toward "Gas" in warm weather as in cold or the charge remaining in the motor may be so rich that it will hinder rather than assist starting.

How to Operate the Autocar

It is well for the beginner to form correct habits of procedure in the routine of starting the car. After assuring yourself that there is a proper supply of water, gasoline and oil in the car, be sure that the clutch is held out of engagement. This may be done by pushing or pulling the outside hand lever toward the rear of the car, thereby setting the emergency brake, and by setting the inner (gear shift) hand lever pawl in second notch from the rear, which is neutral position.

To Start the Motor.—Push in magneto switch and open the throttle partially by moving the lever on the steering wheel from one-third to one-half of its travel upward. Crank the motor, being careful of the manner in which the crank handle is gripped; that is, keep the thumb on the same side as the fingers, never

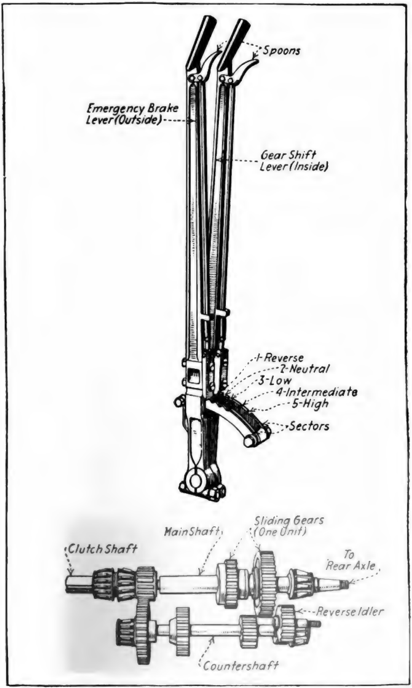

Spoons
Emergency Brake
Lever (Outside)
Gear Shift
Lever (Inside)
1-Reverse
2-Neutral
3-Low
4-Intermediate
5-High
Sectors
Sliding Gears
(One Unit)
Main Shaft
Clutch Shaft
To
Rear Axle
Reverse Idler
Countershaft

Fig. 311.—Control Levers and Gears of Autocar Truck, Showing Progressive Gear Shift System.

Google

gripping between the thumb and fingers. Pull up on crank handle with a quick half turn. Never push down on starting crank. Brisk cranking is necessary to form a proper mixture, and to obtain a proper spark from the magneto. If motor does not start, give the starting crank a quick turn, or, if necessary, several rapid turns, always revolving the crank towards the right. In case the motor does not start readily after following these instructions, or in cold weather, when the gasoline does not vaporize readily until the engine is warmed up, pull out rod extending through the radiator near the starting crank. Then again crank motor as before. As soon as motor has started, immediately push rod back to its original position, as the motor will stop if this is not done. Having started the motor, reach over the dash and retard the throttle to prevent motor racing, then

To Start the Car.—Take position in the seat ready to start the car. With the left foot on the clutch pedal and right foot on the brake pedal the operator grasps the steering wheel with the left hand. While holding out clutch pedal with the left foot, with right hand release emergency brake, holding car with right foot brake if on an incline of road. Then prepare to shift gears as follows: Press the spoon which lifts the pawl from the notch (and allows the gear shift lever to be moved forward), and immediately release spoon so that pawl will fall in third notch, this being low gear. Speed up motor slightly by opening the throttle lever, but do not race the motor. Then gradually let clutch pedal come back and engage clutch, thereby starting the car.

Shifting Gears.—Open throttle slightly farther until car is well under way and begin the progressive changing of gears. First and always in shifting gears throw out the clutch with the left foot (holding clutch out until shift has been made), move gear shift lever as before, forward into fourth position, advance throttle and gradually engage clutch. Repeat this operation in changing from intermediate to fifth position, or high gear. Speed is controlled by advancing or retarding the throttle to meet the various road conditions. It is always advisable to start car on low gear, as this relieves all possible strain on the motor and transmission mechanism. Never attempt to start car with gear shift lever in intermediate or high-speed position. Furthermore, when stopping always bring gear shift lever into neutral position so as to be ready to start as before. In shifting from low gear to reverse, and vice versa, release clutch, but do not move gear shift until car has come to a rest, so as not to abuse the gears, the teeth of which are moving in the opposite direction. Their engagement under these conditions would increase the wear.

The proper shifting of gears is easily understood after practice. The movement should be made quickly, and never with throttle wide open, causing the motor to race. In case the car is standing still and the gear shift lever cannot be moved to position desired, because the edges of the teeth of the transmission gears strike and will not allow the sliding gear to be moved, release the clutch pedal slightly, thus permitting the clutch to partly engage and rotate the clutch shaft. Press out clutch pedal again. While the shaft is rotating the gear shift lever can be moved to any position. Great pressure on the gear shift lever is unnecessary; should be avoided, in fact, as it strains the whole mechanism.

To Stop the Car.—In slowing the speed of the car or stopping, push out the clutch pedal with left foot, then apply the brake pedal gradually with right foot, avoiding sudden pressure, as this will cause the rear wheels to slide without rotating. When the car is brought to a full rest, gradually pull back emergency brake lever, which holds out the clutch and puts on emergency brake at the same time. Always bring the gear shift lever into second notch or neutral position. Pull out switch on front of driver's seat. This short circuits the electric current and motor is brought to a complete rest.

Gear Positions

The action of placing the pawl in the different notches of the sector plate as indicated by the numbers above shifts the gears into their progressive positions, as No. 1, Reverse; No. 2, Neutral; No. 3, Low Speed; No. 4, Intermediate Speed, and No. 5, High Speed. All these are shown at Fig. 311.

Things to Remember

1. Fill radiator with clear water daily.
2. Fill gasoline tank, straining the gasoline through chamois.
3. Fill oiler with good grade of gas engine cylinder oil.

4. Lubricate all parts with medium-bodied oil as per oiling instructions that will be found on chart under driver's seat.

5. With motor running, occasionally look at sight-feed on oiler to see that oil is feeding properly.

6. Keep pneumatic tires properly inflated.

7. Proper adjustment of brakes is very important for the safety of both car and operator.

8. In using brakes always apply pressure gradually.

9. Always let in clutch slowly and easily.

10. Release clutch entirely before shifting gears, and then move shifting lever with a steady pressure.

11. A daily inspection of car should be made, tightening all bolts and nuts that may have jarred loose. A little care in this respect will avoid trouble.

Care and Operation of Bethlehem Trucks

1. Fill radiator with clean water.

2. Check quantity of oil in crankcase of engine by looking at oil gauge on right-hand side of crankcase. There should be sufficient oil in the crankcase at all times to maintain the oil gauge at a point three-quarters of the way up the glass, or higher. Engine must never be run under any circumstances when the oil gauge stands below the center of the glass.

3. Lift seat cushion and connect heavy cable to battery terminal, tightening terminal clamp so as to make good contact.

4. Insert ignition key (shipped in envelope attached to steering wheel) in switch on dash and turn key one-quarter turn to the right to "On" position. Key should always be turned to the right, and must never be left in "On" position if engine stalls.

5. Richen mixture for easy starting by pulling the choker on side of steering column to position marked "Gas." After engine has started, choker should be gradually returned to position marked "Air."

6. Retard spark by pushing inner lever on steering wheel all of the way up the quadrant and partially open throttle by pulling outer lever on steering wheel about one-third of the way down the quadrant.

7. Crank engine by depressing starting button (located in toe boards). Release starting button the moment engine starts. If

engine does not start within a few seconds, release starting button and examine ignition wiring for loose connections, and also see that fuse is in place in clip on engine side of dash. Prolonged cranking with the starting motor will only discharge the storage battery needlessly. Until truck has been driven about two hundred miles, or enough to free the engine bearings, it is advisable to assist the starting motor by using the hand crank, thereby avoiding undue strain on the storage battery.

Lubrication.—After truck has been driven about three hundred miles, drain all oil from engine crankcase, flush thoroughly with kerosene and refill with fresh oil. The engine will give longer service if this procedure is carefully followed each month.

Instructions covering lubrication of all other parts of the truck are given in the lubrication chart on page 42.

Engine.—Firing order 1-3-4-2. When necessary to readjust or grind valves, clearance of .003 inch in the case of inlet valves and .005 inch in the case of exhaust valves should be left between push rod and valve stem when engine is hot. If engine shows a tendency to overheat, make sure that fan belt has sufficient tension to drive fan. Belt can be tightened by loosening pinch-bolt and shifting eccentric at top of fan bracket. Overheating is also often caused by driving with retarded spark. Spark lever should be advanced down quadrant on steering wheel as far as possible without causing engine to knock.

Carburetor.—The carburetor is properly adjusted at the factory. Do not attempt to readjust it unless you are certain it is causing trouble. If, however, readjustment becomes necessary, run engine until thoroughly warm before attempting any readjustment. Close air valve entirely by turning cap to the right as far as possible, then turn one complete revolution to the left. Open throttle about one-third and start engine, turning air valve cap to left until engine runs smoothly. Accelerate engine by opening throttle quickly, keeping spark lever in retarded position. If engine backfires into carburetor, turn small adjusting thumbscrew under air valve chamber upward, to give more tension to air valve spring.

Governor.—The governor is properly adjusted at the factory and should not be readjusted. In case readjustment becomes absolutely necessary for any reason, two keys for governor padlock will be found in envelope attached to steering wheel.

Ignition.—Always fully retard spark before attempting to start engine. Never leave ignition key in "On" position when engine is not running. Always drive with spark advanced as far as possible without causing engine to labor or knock.

Starting-Lighting System.—Never run engine with storage battery disconnected or without proper fuse in fuse clip on engine side of dash. This fuse should be of 20-ampere capacity. If the engine is run under either of the above conditions, the windings of the generator will be burned out. Do not engage starting motor by depressing starting button while flywheel is in motion. This is likely to result in damage to starting gears. Full information in regard to the Gray & Davis starting-lighting system will be found in booklet in tool box.

Storage Battery.—Follow instructions given on plate on dash. Use only distilled water in storage battery. On the first and fifteenth of each month, fill each of the three cells of storage battery with distilled water to a height of about one-quarter inch above top of plates. Grease battery terminals occasionally to prevent corrosion. Full information in regard to the Willard storage battery will be found in booklet in tool box.

Cooling System.—The radiator should be kept nearly full of clean water to assure perfect cooling. Remove drain plug from bottom of radiator occasionally and flush entire cooling system with clean water. When the temperature is below 32 degrees Fahrenheit, the cooling system must be drained if the engine is stopped for any length of time, or an anti-freezing solution must be used. A mixture of wood alcohol and water is the least likely to clog up the small water passages in the radiator core. Never pour cold water into a partially empty cooling system while the engine is hot.

Clutch.—Do not permit clutch pedal to touch floor board when clutch is engaged, as this condition will cause rapid wear of clutch facing. Position of clutch pedal can be easily altered by means of adjusting hub under floor boards. Do not drive with foot resting on clutch pedal. This will also cause slipping in the clutch and very rapid wear on the clutch facing. Full information in regard to the Borg & Beck clutch will be found in chapter on clutches.

Spring Clips.—All spring clip nuts, both front and rear, must be tightened every week for the first four weeks that a new truck is in service. They should also be tightened at frequent intervals thereafter. This precaution is absolutely necessary to prevent spring breakage, which is certain to occur if the unavoidable stretch in the clips is not taken up.

Important General Instructions.—A regular weekly inspection of the truck and tightening of all loose nuts and bolts will prevent serious trouble later on. Inspect level of oil in engine crankcase regularly each day, and follow carefully all instructions given on oiling chart. While your truck is designed to carry a considerable overload in case of emergency, continual overloading will shorten its life. The same effect is produced if the governor is opened and truck driven faster than the speed for which it was designed.

Summary of Important Suggestions to Drivers.—Do lubricate regularly and thoroughly; it prolongs the life of your truck. Don't lock your brakes, thus sliding your wheels; it wears out your tires and puts useless strain on the truck. Do keep your truck clean; grit is to wearing parts what disease is to the human race. Don't accelerate too quickly; it causes the motor to pound and puts needless strain on the truck in general. Do keep your brakes adjusted; "Safety First," while a good motto for all, is doubly applicable as regards the operation of a truck. Don't allow your truck to stand in pools of oil or water; money saved on tires has as much purchasing power as that which is earned otherwise. Your employer knows this. Do inspect and tighten up often; it is unnecessary to quote the old adage in reference to "a stitch in time," etc. Don't fail to heed the truck's request for lubrication, made apparent by a squeak; when this condition is allowed to continue, damage is the inevitable result. Do change gears as necessary; they were put in the truck to avoid undue wear and tear; do your part.

Don't fail to cover the radiator and hood when truck is required to stand in cold weather; the purchase of a new motor, radiator and pump, made necessary by your carelessness, will not tend to boost your stock with your employer. Do have patience with the motor on a cold morning; it will not reach its highest efficiency until it warms up. Don't knock the truck to your employer; remember it is your fellow-workman, and there are thousands of trucks such as yours in operation that are giving perfect service. Find out what is causing any trouble that may develop and take means to eliminate it. If our Service Department can help, we are at your disposal. Do exercise thoughtfulness in picking your route; care in this regard will be compensated for by the extra good service which the truck will render you. Don't speed; you are driving a heavy duty truck, not a speedster. Do keep your truck moving; when running, it's an asset; when standing, a liability. Don't overload; overloaded trucks, like overworked men, break down. Both are of very little value in that condition.

Any truck or trucks, with systematic care outlined and proper lubrication, will give satisfactory and economical service. 1—Any unusual noise is a sign that something needs attention. 2—If car starts to skid, release clutch, but do not apply brakes until car is under control. 3—Using a poor oil or oil that has been used too long in the engine will foul spark plugs. 4—If truck is to be laid up for several weeks, put two tablespoonfuls of oil in each cylinder to prevent rust. 5—Should it become necessary to tow another vehicle or to have the truck towed, be sure that the tow line is hitched to a frame and NOT TO AN AXLE. 6—Always run slowly on wet asphalt and slow down for corners to avoid skidding and to save tires. 7—Do not apply the brakes suddenly, except in cases of emergency. 8—Do not engage clutch when brake is set unless gear lever is in neutral. 9—Do not start motor unless gear lever is in neutral position. 10—Do not allow the truck to stand for more than a few minutes with the engine running. 11—If the motor misses ignitions the trouble is most certain to be in the spark plugs or wiring. 12—Never run the motor at high speed without a load. 13—If the motor has been overloaded so that the water has boiled away, raise the hood and allow it to cool down to normal temperature BEFORE ADDING MORE WATER.

Climbing Hills.—Do not attempt to rush a hill. Shift gears when necessary to prevent unnecessary laboring of the engine, as the hill will be negotiated in less time and the strain on the mechanism will be relieved. If spark control lever is retarded, be sure to advance it after it has been negotiated, for to run with retarded spark will cause engine to overheat.

Descending Hills.—To maintain control of the truck in descending long hills it is advisable to shift to second or first speed and cut off the ignition, using engine as a brake. With the emergency brake and the powerful service brake applied at the proper time to prevent truck gaining momentum, absolute control is assured.

Stopping Truck on Hills.—When truck is allowed to stand on grades, set the emergency brakes. Should the grade be particularly steep or the truck is to be left in this position for an extended period, take the extra precaution of blocking the wheels. When the truck is descending a hill, never attempt to retard its motion by using the reverse gear.

Chuck Holes and Ridges.—When chuck holes, raised crossings or ridges are encountered, allow the truck to enter the depressions slowly, slipping the clutch momentarily and open the throttle just before the front wheels meet the rise. The front wheels will climb these abrupt ridges, so it is absolutely unnecessary to rush the hole to force the front wheels over. Careful handling under such road conditions will prevent undue strain on the springs, which bear the brunt of these sudden shocks.

Sand—Mud—Snow.—The same precautions used in climbing hills are applicable to the negotiations of soft roads of mud, sand or snow. Shift to lower gears before engine begins to labor. This is altogether desirable to prevent overheating of the engine. It is possible, when the truck is mired in soft road-bed, to secure additional traction by turning the front wheels so that they will work against the sides of the rut. With the means of securing additional traction and controlling application of power to all the wheels, provided in our construction, it remains only for the judgment and ability of the driver to meet the special conditions encountered.

Use of Throttle.—When starting through soft spots, do not race the engine before engaging the clutch, for the governor automatically closes the butterfly valve in the inlet manifold, consequently, when the clutch is engaged the motor meets the peak load with small throttle opening. When starting against great road resistance, open the throttle as the clutch is engaged. This will allow the engine to obtain its full charge of fuel at the moment when greatest power is needed.

Don'ts by International Harvester Company

Don't try to make a racing car out of your truck.

Don't start without sufficient oil, water and gas to get back on.

Don't attempt to shift from high speed into intermediate gear when the car is running at a high rate of speed.

Don't leave car without setting emergency brakes.

Don't move the gear shift lever while the clutch is in.

Don't attempt to shift from second to low gear unless the car is running very slowly.

Don't turn corners at high speed.

Don't neglect to turn front wheel against curb when stopping truck on a hill.

Don't drive over railroad crossings without first shifting into second speed.

Don't leave the car without taking out the switch key or placing the same in off position.

Don't drive over rough places when it can be avoided.

Don't blame the truck for trouble that your carelessness has caused.

Don't be afraid to ask for information.

Don't lose your instruction book and repairs list.

Don't leave the car with motor running.

Don't use your truck for joy riding.

Don't allow dirt and oil to accumulate on frame, motor, axles, etc.

Don't screw bolts and nuts hard enough to strip their threads.

Don't forget cotter pins and lock nuts.

Don't run the motor if knocking, pounding, squeaking or grinding.

Don't allow the motor to run at high speed under no load.

Don't attempt to start the engine with the switch turned off, or without gasoline in the tank.

Don't leave the motor overnight in weather cold enough to freeze, without drawing off the water.

Don't crank the motor without first retarding the spark, setting the emergency brake and throwing the gear shifting lever into neutral.

Don't turn steering wheel when car is not in motion. It is hard on the tires.

Don't run with water low in the radiator.

Don't pinch the inner tube when applying or removing an outer casing. Pass the hand around inside before re-applying the outer bead.

Don't try to force a tire onto the wheel. If it goes on unusually hard, look for some trouble. Perhaps the valve stem isn't in place properly.

Don't let the weight rest on a deflated tire. Jack up the wheel or remove the tire.

Don't run on a flat tire. Better run on the rim if only for a short distance.

Don't overload your tires. A tire will give out sooner from overloading than from almost any other cause.

Don't allow oil and grease to accumulate on garage floor.

Don't use tires too small for the service required of them.

Don't neglect the lubrication of any part of the car.

Timely Hints for Good Service

Never start on a trip without attention to oil, gasoline and water.

Always keep your brakes adjusted. It is more necessary to be able to stop the car than to start it.

Don't neglect to keep your lamps filled. You may need the light badly some time.

The truck should not be left alone with the motor running.

Don't drive faster than the governor rating.

Always release the hand brake before attempting to start.

Do not jerk the truck by quick opening of the throttle.

Never forget, above all else, that a truck is a complete power plant, and that you will be repaid in excellence of service many times over for the care and attention given it. It does not pay to overload or overspeed your truck.

Be careful not to turn the hose on the motor when washing your truck; water will short-circuit the ignition.

Do not fill the radiator with cold water when the motor is very hot. It may crack your cylinders.

Don't continue to crank your engine if ignition does not take place after a few revolutions. There is something wrong with your ignition system or the carburetor. Look for the trouble and correct it. Just turning over the engine will not help matters.

Never allow connections on generator, battery or motor to become loose. See that all terminal nuts are pulled up tight and remain so.

Always keep all parts of the truck well lubricated.

It is well to give the truck regular inspection.

Remember that a "stitch in time saves nine."

Don't try to start without the switch turned on.

Always use the best grade of gasoline, as it is the cheapest in the long run.

Don't forget to fill the radiator regularly.

In case you have trouble, don't begin by disassembling everything in sight. Study the symptoms and consult instructions given in Chapter XIII.

See that the water hose connections between engine and radiator are straight, so as not to restrict cooling system.

When ordering repair parts, always give chassis number.

Anti-Skid and Traction Devices.—One of the disadvantages of the wheel as a traction device is that it may not secure sufficient grip when road conditions are unfavorable and not enough traction is obtained to drive the truck. Various expedients have been tried to increase the traction of motor truck wheels. When the roads are very soft and the surface is composed of sand, the ordinary wheel may not have sufficient gripping surface to carry the load without sinking into the soft road material. In such a case extension rims may be provided which will give a greater supporting area. To obtain traction when roads are covered with mud or snow and prevent the wheels spinning when the power is applied or the entire truck skidding when the brakes are used has been a problem that has called for considerable ingenuity on the part of inventors for its solution. Special forms of tires having sculptured treads, as previously described, have been used when of the pneumatic form.

Two forms of solid rubber tires are shown at Fig. 312 that are intended to not only provide superior traction, but also to prevent skidding. Both are Kelly-Springfield designs. That at A is a sectional block tire in which the tread is formed in a series of removable blocks held in a steel base instead of the usual solid, endless band structure. In the form shown at B notches are cut in the sides of the tire, so as to provide an irregular surface that will have greater traction than a smooth tread and yet not ride "bumpy" as sectional tires are apt to.

The Weed tire chains such as shown at C are the simplest and most easily applied device to prevent skidding and to secure greater traction. These consist of a series of cross chains that are kept in place by means of circumferential chains running close to the wheel felloe. The chains are not put on so tightly that they will stay in one place and cut into the tires, but are installed loosely enough so that they can change their position as the wheel revolves and distribute their pressure over the entire surface of the tread. It is not always possible to install the chains of the Weed construction, so modifications have been used in which the cross chains are secured to hooks which are attached to I-bolts passing through the wheel felloe as at D, or to special clamp fittings which are attached to wooden spokes as outlined at E. When steel wheels of the disc form are used special hooks are sometimes riveted to the disc near the rim, to which the chain ends may be fastened.

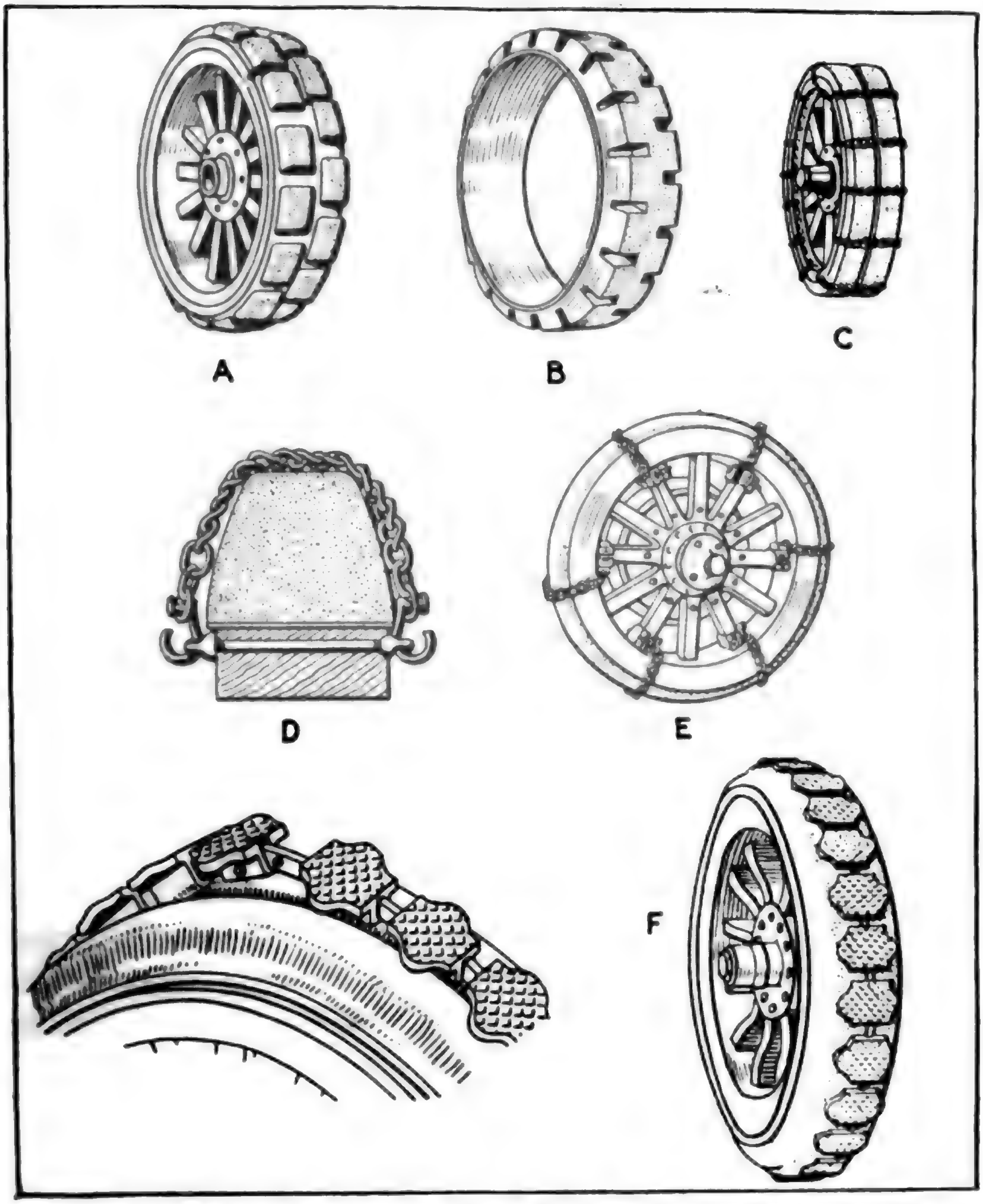


Fig. 312.—Anti-skid Devices for Truck Wheels Assist in Securing Traction on Slippery Roads.

The non-skid tread device shown at Fig. 312, F, is an English design, and has been devised for use with twin-tired motor truck wheels. It is composed of a number of separate dropped forge steel links which may be removed and renewed without difficulty as they wear. It is intended to fit loosely in the space between the tires and be free enough to creep around the wheel. This reduces liability of damaging the tires, and also provides a self-cleaning feature.

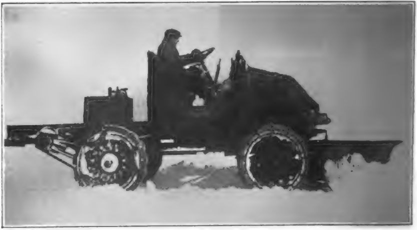


Fig. 313.—Two Types of Traction Devices for Motor Truck Wheels.

The special application of a Kelly Springfield truck tractor for snow-plowing purposes, shown at Fig. 313, depicts clearly two forms of traction devices. The front wheels are equipped with anti-skid chains of the usual form while the rear wheels, which are shod with sectional block tires, are provided with traction devices made of forged steel bars held in place by bolts passing through the lower end and under the wheel felloe.

Extension Rims for Sand.—The ordinary solid rubber tire used on motor trucks is a very satisfactory wheel tread for hard roads, but it does not have sufficient area to keep the wheels from cutting into sand or soft soil. The device shown in the accompanying illustration is a simple contrivance that can be attached to any truck wheel to prevent loaded trucks from settling down in soft roads or fields. If a modern Robinson Crusoe should suddenly come upon the tracks of a "sand growser" equipped California orchard truck in the deep sands of his desert island, he would undoubtedly wrinkle his brow in perplexity and ask himself what manner of machine this could be—for the tracks would be neither those of an ordinary truck nor yet of a tractor. The deep impressions would have almost the breadth

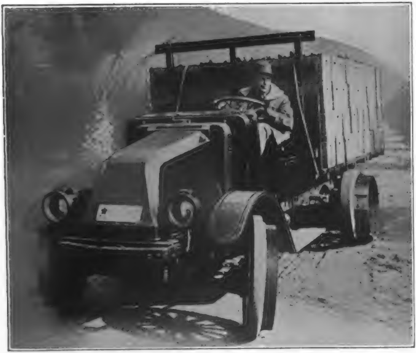


Fig. 314.—I. H. C. Truck Equipped with "Sand Growsers" to Increase Traction.

of tractor drive wheels, but they would be also of two depths—"steps" on the sands of progress—and the desert island.

The "sand growser," however, is now a reality in the orange groves of California. As will be noted from the illustration, this attachment consists of an "extension rim" on each wheel of the truck. When the wheels of the loaded vehicle begin to sink into the loose sand or soft earth of the orchard, the "growsers" reinforce the tires, doubling the soil resistance and traction surface. The rear growsers are furnished with sand lugs, to give added traction when the going becomes hard and heavy. The "sand growsers" clear the road by several inches when traveling on a smooth highway. Trucks so equipped collect the fruit in the orchards (the truck in the illustration is bringing out over 4,000 pounds of oranges), and later haul the packed crates to the city markets. Mr. J. Reynolds, a newspaper man and fruit grower of La Verne, California, is the owner of the "sand-growser" reinforced truck shown on page 515.

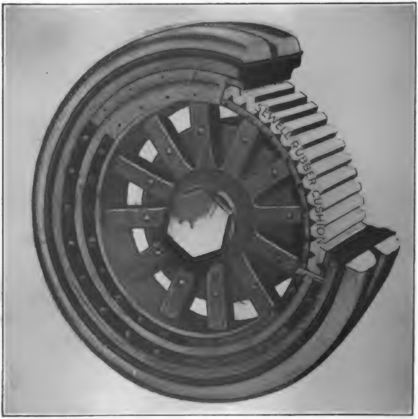


Fig. 314A.—The Sewall Cushion Wheel for Motor Trucks Employs a Special Resilient Rubber Filling between Felloe and Wheel Carrying Rim.

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CHAPTER X

SPECIAL TRUCK APPLICATIONS AND BODY DESIGNS

Truck Loading Devices—Removable Rack Bodies—Utility of Winches—Drop Side Truck Body—Cranes for Loading and Unloading—Conveyor Loaders and Coal Pockets—Specifications Type "A" Scoop Conveyor—Dumping Bodies and Hoists—Hoist Construction—Efficient Hand Operated Hoists—Directions for Mounting Columbian Lightning Hoist—Operation of Wood Hydraulic Hoist—Pierce-Arrow Hydraulic Hoist—Suggestions for the Care of Hoist—Angle of Slide—Angle of Repose—Portable Cranes and Derricks—Fire Department Wrecking Truck — Motor Driven Fire Apparatus — Tractors Used for Long Apparatus—Combination Apparatus—Fire Apparatus Equipment—Motor Trucks for Municipal Use—Special Duty Motor Trucks—Combination Bodies—Motor Truck Body for Pipe—Combined Manure Spreader and Unloader—Special Carrier for Lumber—Armored Automobiles—Mobile Repair Shops—Utility of Tractors—Trailer Types—Drawbar Pull of Motor Trucks—How to Use Tractive Force Chart—Grade Determination.

Truck-Loading Devices.—Whenever heavy materials or quantities of loose substances have to be loaded into trucks, it requires considerable thought to devise means to reduce the time required for loading in order that this expensive item may be reduced as low as possible. The length of time for loading certain materials is often a more serious factor than that of unloading, and motor truck builders and users are constantly trying to reduce the time consumed in this operation. Inventors of new devices to facilitate handling any of the vast number of materials hauled by trucks should be given every encouragement in devising both loading and unloading means.

Large and bulky materials, such as baled hay and cotton, crates, barrels, boxes, furniture and other freight of that nature, is easily handled because they may be moved from the loading platform directly to the truck body and stowed away very easily by the driver and his helper or by special roustabouts employed for that purpose. Where a large variety of freight is handled that differs greatly in size and weight of packages, such as in the express business and in furniture moving, it is necessary to place the main reliance on manual labor. Materials such as coal, dirt, ashes, gravel, road metal and similar substances that is usually piled loosely at storage points, presents a problem that is solved by using various types of mechanical wagon loaders and scoop or bucket loaders moved by conveyor mechanism, as will be described. Such mechanical loading means greatly reduce the cost of loading a truck.

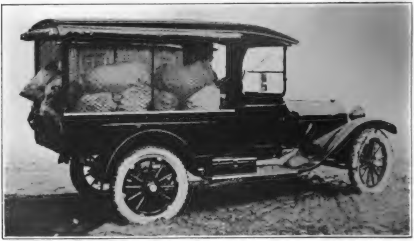

Fig. 315.—Dodge Bros. Chassis with Screen Side Express Body.

With a force of several hand shovelers a certain amount of work can be completed in twenty minutes. With a mechanical loader and one shoveler who does not have heavy lifting to do but merely to keep the material piled so the buckets will feed into it, will do the same amount of work in one-tenth the time. It has been estimated that the labor cost for transferring crushed stone from the ground to the motor truck body costs fifteen to twenty cents per cubic yard, if done by manual labor. With a mechanical loader the same work can be accomplished for two and a half cents per cubic yard. In contracting work it is apparent that the steam shovel used in excavating can dump its load directly into the truck body, as shown at Fig. 317, which shows a number of Kelley trucks working on a big construction job.

Removable Rack Bodies.—In certain lines of business, such as department store delivery, wholesale grocer, or in any industry where a large number of packages that do not vary too much

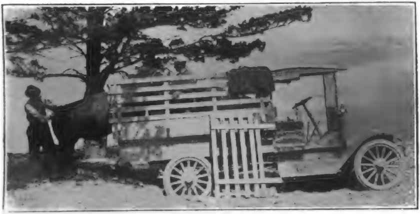

Fig. 316.—Light Truck with Rack Sides Can Carry Cattle.

in size are to be handled, the removable rack system, such as shown at Figs. 318 and 319, is an important factor in reducing both loading and unloading costs. They are especially valuable in moving goods from a warehouse to retail stores or from a main station to delivery stations in definite districts where lighter trucks or parcel cars do the distributing to the individual consumer. Such demountable racks are simply constructed and are provided with substantial wheels. If heavy material is to be

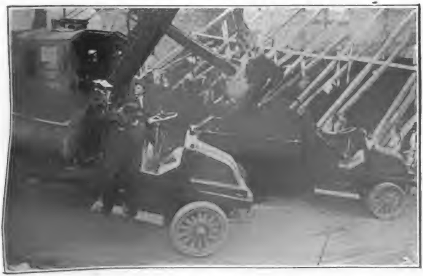

Fig. 317.—In Excavating Work, Trucks May Be Loaded Economically with a Steam Shovel.

handled, such as brick, tile, paving blocks or boxes of canned goods, the rack is more substantial in construction and is fitted with wheels adapted to run on rails so the loaded rack can be easily moved from the loading platform to the truck chassis. After the rack is in place it may be held by hooked anchorage rods on each side of the chassis, that are provided with turn buckles, as shown at Fig. 319. For handling light goods, the rack may be lifted into the body over the lowered tail gate. Deliveries of the numerous parcels that go out of a department store are facilitated by using fiber containers, or large baskets about four feet wide by six feet long and four feet in depth, provided with wheels at the bottom so they can be readily moved from the packing-room to the loading platform, and from that point to the truck body.

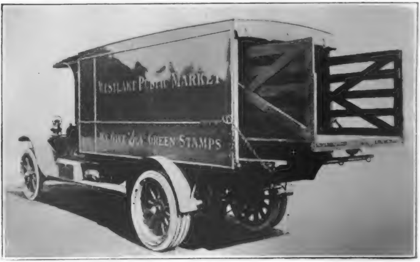

Fig. 318.—Light Removable Rack Body Suitable for Grocery Store Delivery Purposes.

Utility of Winches.—If a truck is intended for handling heavy material, it is found of great advantage to provide a davit at the side from which a chain hoist is suspended so that the heavy packages may be easily lifted into the main body. A number of trucks designed for special duty work are provided with winches which are mounted on the truck platform at the front end back of the driver's seat or at the rear of the chassis, as shown at Fig. 320. These are usually operated by power take-

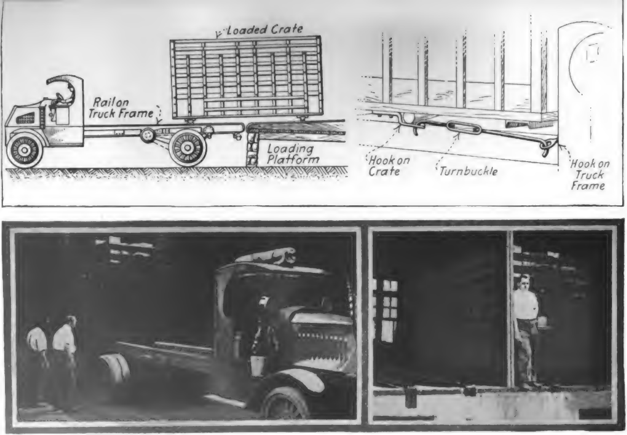
Loaded Crate
Rail on Truck Frame
Loading Platform
Hook on Crate
Turnbuckle
Hook on Truck Frame

Fig. 319.—Diagram and Photos Showing Utility of Removable Rack Body and How it May be Held on Chassis.

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off from the engine or change speed gear, and are provided with brakes conveniently placed so that they may be readily controlled. A large number of the military trucks used by the Ordnance and Engineering branches of the army were provided with winches, and they are also of material benefit in making the work of the general contractor easier. A good example of the practical use of a winch is when employed by a piano or safe mover, in which case the truck engine not only furnishes the power for delivering the heavy object, but also unloads it from the truck body and raises it to whatever height is desired, if its destination is a modern multi-story apartment house or business building.

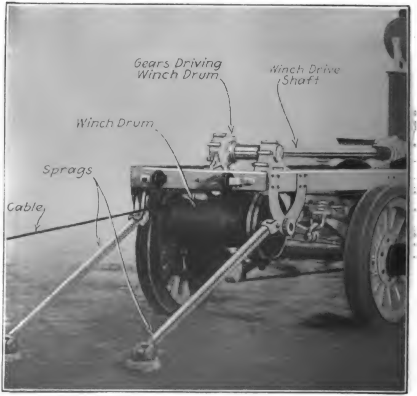


Fig. 320.—How Engine-Driven Winch is Installed in a Motor Truck Chassis.

Drop Side Truck Body.—A bale of cotton weighs 500 pounds. Hoisting these little packages over the side of a motor truck is, therefore, more or less of a back-breaking task. The Georgia planters who own the motor truck shown in the illustration at Fig. 321 have eliminated an extra hoist and saved many back sprains by providing hinged sides for their motor truck. This also makes it possible to haul on a flat bed heavy loads wider than the ordinary truck box, not only saving the box from damage, but greatly facilitating loading and unloading.

Cranes for Loading and Unloading.—Keeping an eye on the cost-per-unit of handling goods has resulted in the Wilcox & Gibbs Sewing Machine Co. devising labor- and time-saving methods that are helpful and which might not have been developed if they, as so many truck owners, watched only such items in haulage and delivery as the visible costs of gasoline, oil and repairs and desired only to increase their truck mileage. This firm operates from its New York office nine trucks—seven Macks, ranging from an AC of 5½ tons down to an AB two-tonner, one G.M.C. of ⅜ ton capacity, and a Locomobile touring car rebuilt to carry ¾ ton. Variety enough to learn facts on both delivery and haulage, for their transportation system requires both.

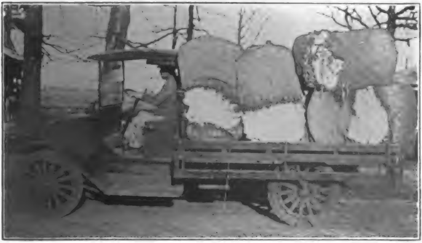


Fig. 321—Drop Side Truck for Carrying Cotton Bales.

That the Wilcox & Gibbs Sewing Machine Co. appreciates speed is proven by its product—the sewing machine that they claim does the greatest amount of work in the shortest time. The experience gained in developing this time-saving machine has been applied to the handling of their trucks and accounts for the ingenuity displayed.

For over half a century Wilcox & Gibbs have been making sewing machines at Poughkeepsie and have discovered that time and labor could be saved by having an assembly plant for some of their models in New York City; so, when a few years ago plans were laid for their garage in New York, they decided to use the upper floors for assembly rooms. No time is wasted by trucks going back and forth from the shop to the garage morning and night. Parts are brought in by trucks from the freight terminals and in many cases direct from the factory, 88 miles away.

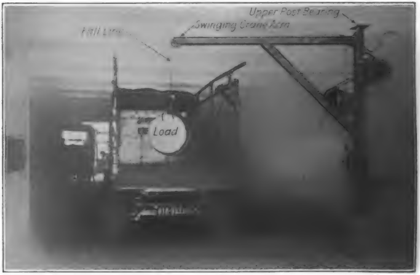


Fig. 322.—Electrically Operated Loading Crane for Warehouse Use.

In connection with this trip it is interesting to note that as there are a number of bridges to be crossed en route, the headroom of the smallest being 10½ feet, the ceiling of the garage was made with the same headroom, so there would be no possibility of stacking goods on the trucks too high only to have them torn off a few hours later by a steel girder. No one need measure or worry about the height of the load, for when the ceiling is reached, that's the limit.

As the trucks pull in and stop at the elevator they are unloaded by a simple and ingenious crane, shown at Fig. 322, which was designed by F. L. Mitchell, who is in charge of the truck transportation work for the company. The crane is operated by one man and easily and quickly lifts loads up to 1,500 pounds. The power is derived from an electric motor of 3 horsepower, and the arm moves in an arc which swings directly from the center of the truck to the platform before the elevator. In this way the crane is unloading the goods in the proper place as the elevator is making its trips. It does the work of four men in one-quarter of the time and does away with the use of skids, rollers, bars, and the usual paraphernalia employed in the loading and unloading of heavy articles from trucks. Here every morning the trucks that get their deliveries for the day from this depot load and get out on time.

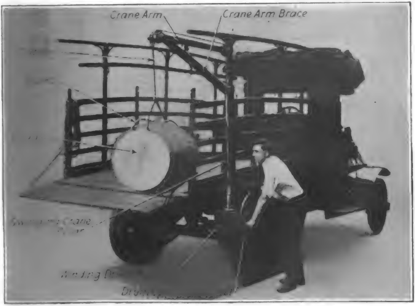


Fig. 323.—Small Hand Operated Crane Attached to Truck Facilitates Loading and Unloading Heavy Objects.

So useful has this crane proven that Mr. Mitchell has designed a smaller one, for use on the truck itself, capable of lifting from 1,200 to 1,400 pounds, for service wherever the truck might have use for it. This, as shown in the illustration at Fig. 323, is mounted on the side of the body where it can be swung back out of the way when not in use without taking up any of the valuable space of the truck platform. Its position near the tail board enables it to lift a load from any position within range of the radius of the arm and place it well forward on the truck Tests have proven that a truck can be loaded with drums of oil weighing about 400 pounds by one man more rapidly than two men could load it by rolling the drums up on skids, which is the usual method, and it is conceded that drums and barrels, because their shape permits rolling, are more easily handled than the usual crate or box, and so, in the handling of the latter, even a greater percentage of time must be saved.

At first glance it might seem to be an advantage to have this crane power driven, but hand labor in this case is actually an advantage, in addition to being cheaper both as to first cost. installation and upkeep. This crane is a one-man crane. From the position of the handle the operator can see where he is depositing his load and when he has reached the ground, which is essential in the case of fragile goods. In the case of a power-driven crane it would be necessary for him to make several trips to the starting lever at the driver's seat, for the cost of running the controls back to the tail and the subsequent upkeep would make it impractical. Really, to be used efficiently, a power-driven crane requires two men—one to work the controls and the other to place the load. With this crane, however, one man is all that is needed. It has been found that a pair of grapple hooks will hold a load of almost any shape or size, and only very heavy loads require the use of a sling.

The heavy duty trucks are used for hauling material to and from the factory and in assisting the two-tonners to handle the freight to and from the freight terminals. The smaller trucks of ¾-ton capacity, and sometimes the two-ton trucks, are used in making deliveries to purchasers in homes and factories in the city and adjacent suburbs. A careful eye is kept on the running of the trucks, and they are maintained to give their utmost performance at all times. The policy of "run her as long as she'll run" is not favored here, for it is realized that prevention is cheaper than cure. It has been found that one man—a good one, of course, that knows his job—is all that is needed to keep the fleet in perfect running condition.

Conveyor Loaders and Pockets.—There are certain materials that can very easily be handled by portable wagon loaders which eliminate a great amount of hand shoveling. A variety of these

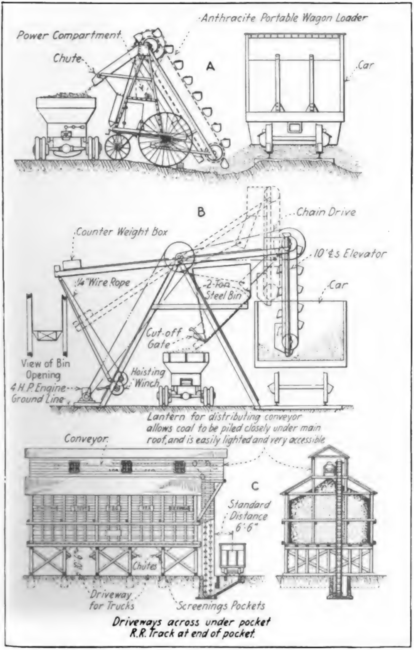

Anthracite Portable Wagon Loader
Power Compartment
Chute
A
Car
B
Chain Drive
Counter Weight Box
10'ₜs Elevator
1/4" Wire Rope
2-Ton Steel Bin
Car
View of Bin Opening
Cut-off Gate
Hoisting Winch
4 H.P. Engine
Ground Line
Lantern for distributing conveyor allows coal to be piled closely under main roof, and is easily lighted and very accessible
Conveyor
C
Standard Distance 6'6"
10'6"
Chutes
Driveway for Trucks
Screenings Pockets
Driveways across under pocket
R.R. Track at end of pocket

Fig. 324.—Diagrams Showing Various Forms of Conveyors for Loading Motor Trucks with Coal and Similar Materials.

devices used in the coal industry are shown at Fig. 324. At A, the portable wagon loader is shown. This consists of a bucket conveyor which lifts the coal or similar material to a chute at the top which directs it into the truck body. The material is unloaded from hopper bottom or bottom dump gondola cars and is picked up from the pile by the bucket conveyor. This is mounted on wheels so it can be easily moved about and also carries its source of power, which may be either an electric motor or a gasoline engine on the same frame. Another form of scoop conveyor which may be used for unloading a car is shown at B. In this the material is lifted into a hopper bottom steel bin of large capacity which is carried high enough on a trestle work so the motor truck can be driven under it to be loaded.

The construction at C shows the conventional form of coal pocket, in which a bucket conveyor, in connection with a horizontal conveyor, will lift the coal from the pit in which it is discharged from the bottom dump gondola car to whatever compartment is desired. As many compartments are provided as there are materials to be stored and, while those outlined are for different grades of coal, it is apparent that gravel road metal. or any other material of that nature, could be disposed of in the same manner. Driveways are provided under the storage compartment in which the trucks are driven. The material is loaded into the truck body by suitable chutes having control gates to regulate the flow of material.

Specifications Type "A" Scoop Conveyor.—Both the 12-inch and 16-inch sizes, with either high flighted or low cleated belt, will carry one ton per minute of material weighing fifty pounds per cubic foot, providing the trough is kept even full. The belt on the 16-inch size travels at a slower speed because it is intended only for handling larger size pieces than can be safely handled on the 12-inch size. For handling material containing cubes measuring over nine inches, the makers, the Portable Machinery Co., Inc., Passaic, N. J., recommend the 16-inch size.

In feeding the scoop conveyor from the storage pile, one man can feed one ton of material that will pass a one-inch ring in one and one-half minutes, providing the storage pile is eight feet or over in height. If the material is large in size or the storage pile is low, it will require several men to feed the machine to its full capacity.

Under ordinary conditions, the cost of electric current to operate motors fitted to the various size scoop conveyors is from four to six cents per hour. If operated by gasoline engine, it requires from two to four gallons per ten hours' continuous operation. The conveying belt which is furnished with the scoop conveyor is of high grade four-ply heavy duck and rubber construction, fitted with either high arched rubber and duck carrying flights or low cross cleats, depending on the kind of material to be conveyed. The belt travels at a speed of about 170 feet per minute.

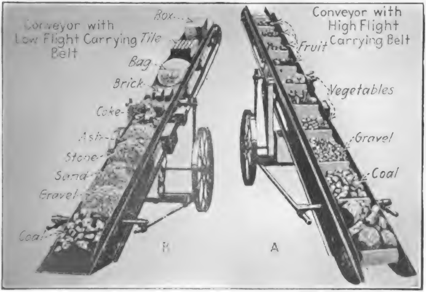

Conveyor with Low Flight Carrying Belt
Box
Tile
Bag
Brick
Coke
Ash
Stone
Sand
Gravel
Coal
B
A
Conveyor with High Flight Carrying Belt
Fruit
Vegetables
Gravel
Coal

Fig. 325.—Portable Conveyor for Loading Motor Trucks.

The manufacturers guarantee that the scoop conveyor repair costs through wear, including conveying belt renewals, will not be over one and one-half cents per ton of material handled when conveying coal, coke, ashes, sand, crushed stone or similar material. The object of the scoop conveyor is to provide a machine that is convenient to use. Its first cost is low; it is easy to move and feed. It has a wide range of applications. The scoop conveyor is a light weight portable belt conveyor designed to be handled by one man and to assist the hand shoveler in moving materials such as noted in the above illustrations.

The receiving or feed end of both the High-Flight and Low-

Cleat belt machines can be completely buried into the material to be conveyed. This allows scraping the material onto the carrying belt, instead of lifting it by shovelfuls into receiving hoppers fitted to ordinary portable belt conveyors, and saves 50 per cent of the labor in feeding.

The high-flight belt type shown at Fig. 325, A, is intended only to handle rounds and cubes that are not mixed with at least 50 per cent of fines, such as gravel without sand or egg. stove and R.O.M. coal without fines. It will also handle fruit or vegetables without cutting, chafing or bruising them while they are being conveyed.

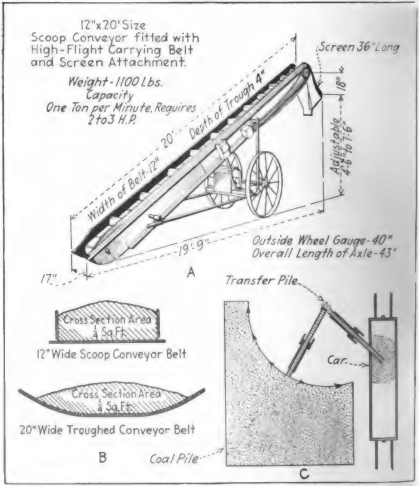

12"x20' Size
Scoop Conveyor fitted with High-Flight Carrying Belt and Screen Attachment.
Weight-1100 Lbs.
Capacity
One Ton per Minute. Requires 2 to 3 H.P.
Screen 36" Long
18"
Depth of Trough 4"
20'
Adjustable 4'6" to 7'6"
Width of Belt-12"
Outside Wheel Gauge-40"
Overall Length of Axle-43"
19'9"
17"
A
Cross Section Area $\frac{1}{4}$ Sq.Ft.
12" Wide Scoop Conveyor Belt
Cross Section Area $\frac{1}{4}$ Sq.Ft.
20" Wide Troughed Conveyor Belt
B
Transfer Pile
Car
Coal Pile
C

Fig. 326.—Features of the Portable Conveyor for Loading Motor Trucks Economically.

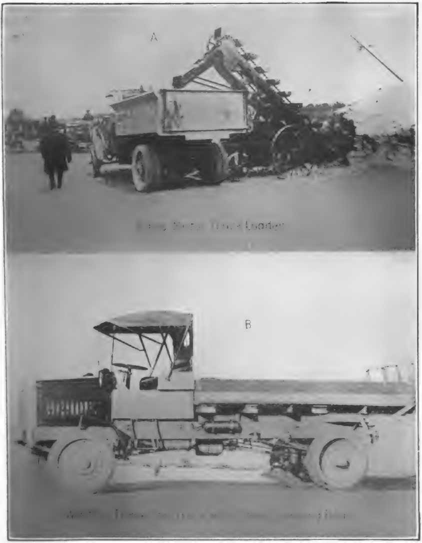


Fig. 327.—A Shows Haiss Motor Truck Loader in Use. .The Illustration at B Depicts Steel Dump Body Well Adapted for Use in Handling Coal and Similar Materials.

The low cleat belt form depicted at Fig. 325, B, will handle large oblong pieces or flats with or without a mixture of fines. It will also handle large rounds and cubes, providing they are mixed with at least 50 per cent of fines. "Fines" are pieces under one inch in size and keep rounds and cubes from rolling backward.

The skirt plates on a 12-inch wide scoop conveyor form a trough, giving the belt a carrying capacity equal to a 20-inch wide troughed belt. The material carried in the narrow trough of the scoop conveyor, being held together by the skirt plates, will not roll back as easily as it does on a troughbed belt, where it is allowed to spread. (See Fig. 326, B.) It requires a 30-foot long troughbed belt conveyor to safely carry a given material as high as a 24-foot long scoop conveyor will carry it. Two new 12-inch x 24-inch scoop conveyor belts can be purchased for the price of one 20-inch x 30-inch troughbed conveyor belt, cutting cost of belt renewals in two.

Inclined portable belt conveyors over 24 feet long become difficult to handle and keep adjusted. If it is necessary to move material a greater distance, we recommend using two conveyors, each with its independent drive. This allows swinging the second conveyor around at various angles without interfering with the discharge end of the first conveyor or vice versa, as is clearly shown at Fig. 326, C.

Dumping Bodies and Hoists.—Many forms of dumping bodies have been designed to permit of rapid unloading, and these are used to a large extent by contractors and also by dealers in coal and other fuels. Dumping bodies are made in infinite variety and different constructions, according to the nature of the materials carried. Some dump from the sides, others are a tilting type in which the load is discharged to one side; forms adapted for use with trailers are bottom dump in a number of cases. Obviously, the bottom discharge construction would not be as practical on a motor truck chassis as on a trailer because of the parts of the mechanism that are carried beneath the body. The usual form of a dumping body, such as shown at Fig. 327, discharges through a tail-gate at the back end or it may have a hopper-like back which makes it unnecessary to use a tail-gate. Some bodies are dumped automatically without elevating the front end because the material is carried by a slanting or angular bottom, but most dumping bodies must be raised at the front in order to give the body sufficient angular displacement so the material will slide out by gravity.

Some forms of body used in the coal industry are of the automatic dumping type, as shown at Fig. 328, A, but combine an elevating feature so the load may be raised six or eight feet higher than the chassis, as outlined at Fig. 328, B, and a greater

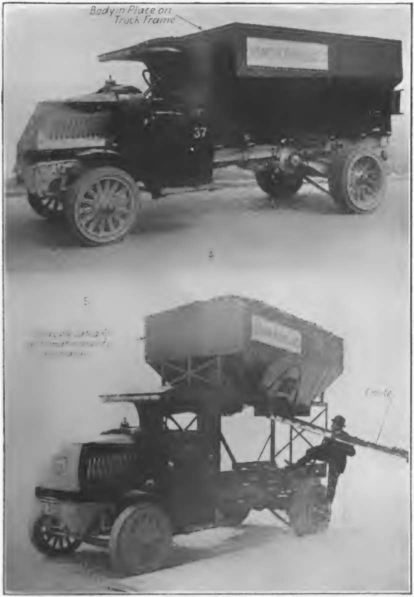


Fig. 328.—Mack Truck Equipped with Elevating Gravity Discharge Coal Body.

gravity head obtained so that the coal may be discharged down a long chute over a sidewalk and into a basement window or coal hole even if the truck remains close to the curb. The combined elevating and dumping bodies usually have a side discharge located at the bottom to which the chute may be easily attached.

In handling certain materials, such as coal of different grades or road-building material, the dumping body may be divided

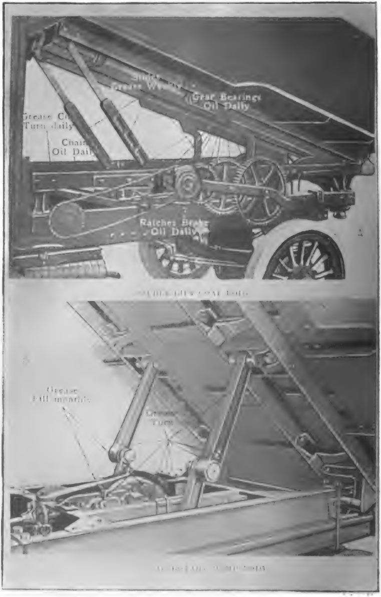

Slides Grease Weekly
Gear Bearings Oil Daily
Grease Cup Turn daily
Chain Oil Daily
Ratchet Brake Oil Daily
Grease Fill monthly
Grease Turn

Fig. 329.—Two Forms of Hoisting Mechanism Used on Autocar Trucks.

into compartments so only the contents of one compartment may be discharged, if desired. This is very useful in the retail coal trade where a five-ton capacity chassis is used for delivering small quantities. It may be divided into five compartments, each holding one ton, so that five customers wanting but one ton each of a given grade or a customer wanting several grades could be served on one trip. This is also an advantage in the contracting industry, as one compartment may be filled with gravel, another with coarse road metal, and a third with finer top dressing. If only a small section of road was to be repaired it is evident that sufficient material could be hauled on one trip if a compartment body was used.

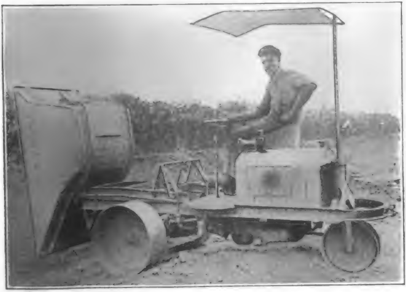


Fig. 330.—Clark Truck-Tractor Fitted with Simple Dump Body for Contractor's Use.

Hoist Construction.—The hoisting mechanisms are of two forms: those in which the gearing and lifting mechanism are turned by a hand crank and the other type in which the engine power is utilized to do the work, either through the medium of a hydraulic hoist, as at Fig. 328, or by screw gearing, as shown at Fig. 329, A. Hydraulic hoists are generally favored because they are simple in construction and very powerful. The construction of the Wood hydraulic hoist is shown at Fig. 331. This is usually installed between the driver's seat and the front end of the body. The main portion of the hoist is a hydraulic cylinder in which a piston moves, the construction being very similar to that of a plunger elevator. The surface of the piston rests on a quantity of oil which is pumped under it by means of a rotary gear pump. By having the entire cylinder barrel filled with oil, it will be evident that if a valve is turned so the pump takes the oil from the top of the piston and directs it to the space below the piston that that member will be raised. A reverse action will cause the piston to descend in the cylinder. The rotary gear pump, as will be evident from the accompanying illustration, is driven by chain and sprocket mechanism from some

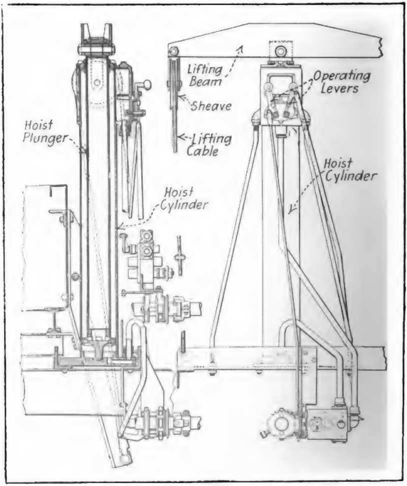

Lifting Beam
Operating Levers
Sheave
Hoist Plunger
Lifting Cable
Hoist Cylinder
Hoist Cylinder

Fig. 331.—Diagrams Showing Construction of Wood Hydraulic Hoist.

part of the power transmission system. The plunger carries a beam to which sheaves are attached. A wire rope anchored to the chassis frame at one end passes over each pulley and is con-

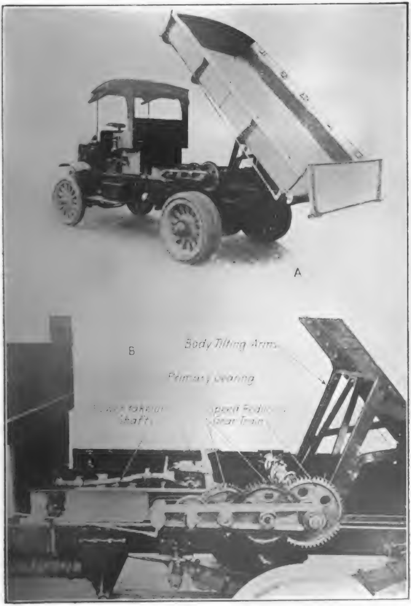

A
B
Body Tilting Arms
Primary Gearing
Power Takeoff Shaft
Speed Reducing Gear Train

Fig. 332.—Power Operated Hoist in which Mechanical Gearing and Levers are Used to Raise Body.

nected at the lower end to a lifting arm fastened to the front end of the body. The construction is such that the piston movement is multiplied in some forms and the plunger need only lift

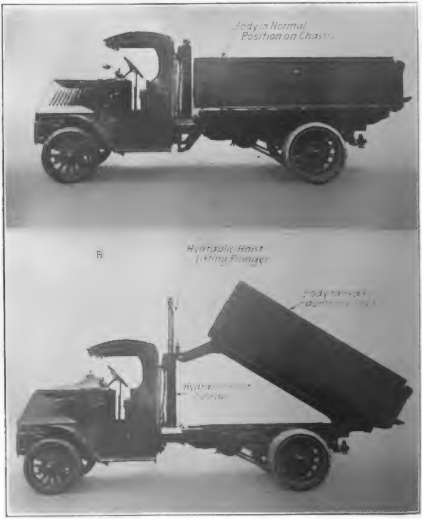

Body in Normal
Position on Chassis
B
Hydraulic Hoist
Lifting Plunger

Fig. 333.—Mack Truck with Hydraulic Hoist Operated Dump Body.

half as high as the body. In other forms the plunger must travel as much as the body does.

Truck With Gear Hoist.—The illustration at Fig. 332 shows a Brockway 3½-ton contractor's steel body, with gear power dump, the gear hoist being illustrated in Fig. 333, showing power head bolted to transmission gear case connected with miter gear bolted to cross member of sub-frame and connected with a double universal jointed shaft. From the miter gear a universal jointed shaft extends to the train of gears mounted on the side of the sub-frame which winds a chain on the rear cross shaft, thereby

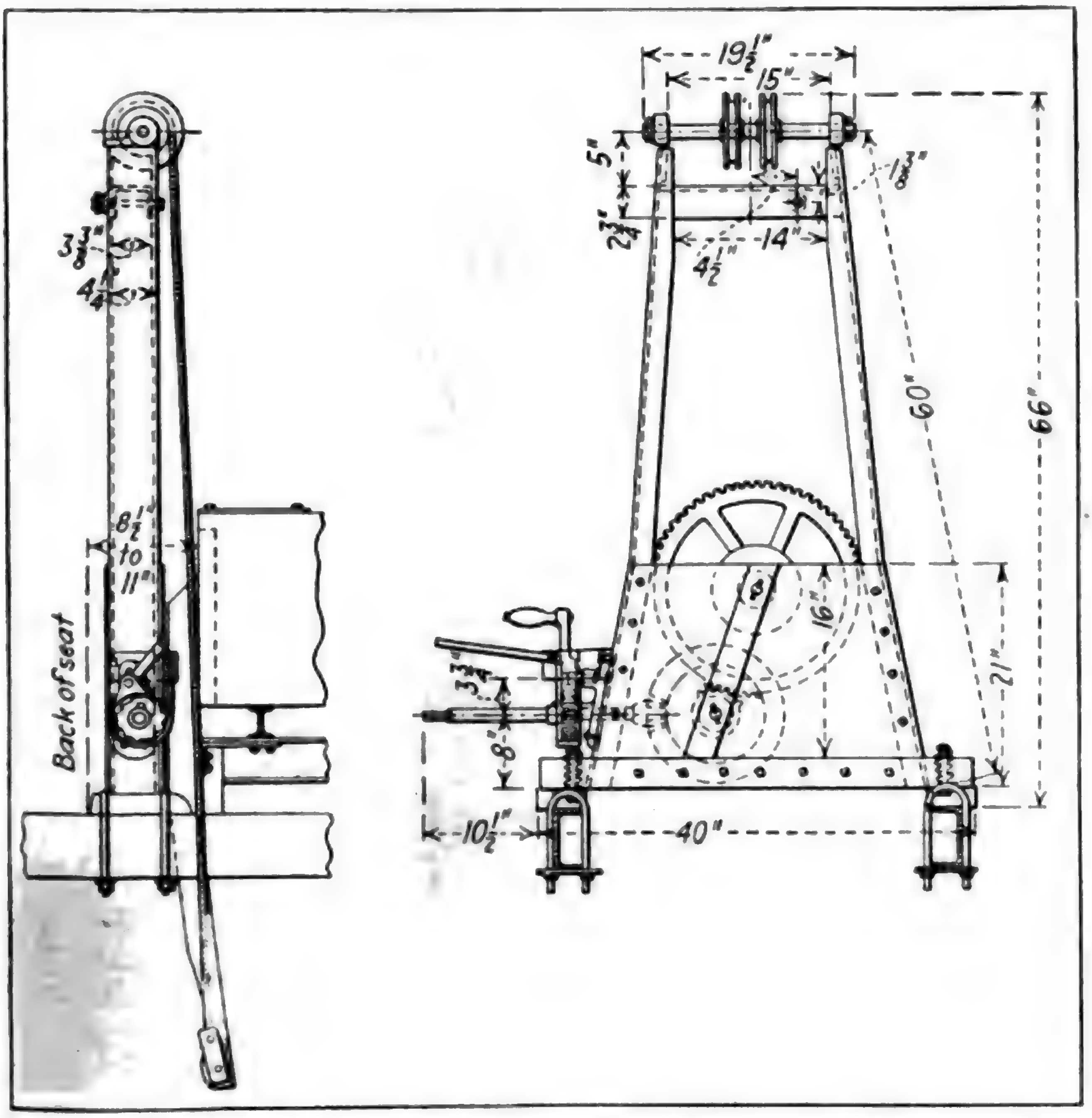


Fig. 334A.—Diagram Showing Details of the Columbian Lightning Hoist.

raising the arm which elevates the body. The gears are cut and run in ample size bronze bushings. By mounting the gear hoist under the body where it is entirely out of the way, while at the same time most accessible, it permits the body to come up directly back of the driver's seat, giving better balance to the load, while at the same time it allows the chassis to be close coupled, so that the wheel base is only 120 inches, thereby giving greater strength and short turning radius. The steel body is constructed of $^3/_{16}$-inch stock and has a capacity level full of three cubic yards, while the flare sides are equipped with slots in which to attach side boards, for hauling cinders, ashes, or other light, bulky materials.

Efficient Hand Operated Hoist.—The principal objection to hand operated hoists is the uncertainty of practical operation by

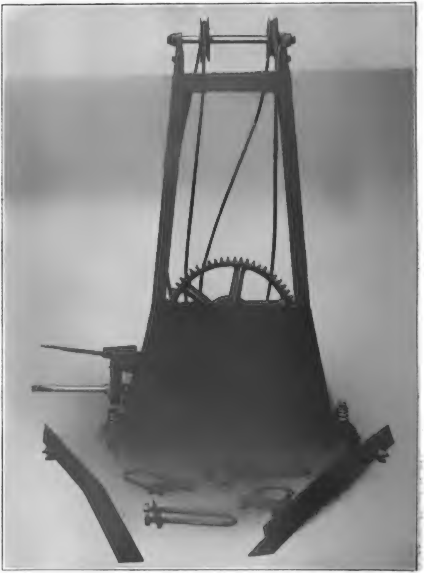


Fig. 334B.—The Columbian Lightning Hoist is Hand Operated and Simple in Construction.

one man. This is overcome in the Columbian Lightning Hoist, which is manufactured by the Columbian Steel Tank Co., Kansas City, Mo. The hoist is so constructed that it will fit any chassis and can be mounted in a few minutes without drilling holes in the frame. The dimensions are shown in design drawng at Fig. 334, A, which also outlines the multiplying gearing. It operates easily and elevates loads from one to five tons with but one man at the crank. The hoist will raise the dump bed to an incline of from 30 to 50 degrees in approximately two minutes.

The motion is obtained by a crank on the outside of the hoist frame, operated by man power. The shaft on which the crank its is provided with a ratchet and safety pawl, these close to the hoist frame on the outside surface. On the inside end of the shaft is fastened a bevel pinion which meshes with a large bevel gear. On the shaft which carries this bevel gear is attached a spur pinion, which drives the hoisting drum gear.

It will be noticed from the illustration at Fig. 334, B, that the hoist is neat in appearance, having plain lines, and the gears are concealed so that there is no danger to the man operating it. The overlapping coils of rope on the drum are designed to produce a rapid lifting speed with a uniform effort at the crank. As the rope coils in layers upon the drum, the diameter becomng larger, the hoist develops more speed and the load is raised faster with no extra effort on the part of the operator. The hoist is set on the chassis frame and attached with heavy sliding U bolts, which hold it in a rigid, upright position. The hoist s shown installed at Fig. 336, A and B.

The frame of the hoist is made of steel plate, the various sections being held together with bolts. The large gear and drum are cast in one piece. The pinion is made of bronze. The height over all of the hoist is 66 inches, length 50½ inches and width ½ to 11 inches, which includes the swing of the steel cables used for hoisting.

Directions for Mounting Columbian Lightning Hoist.—First: The hoist must be mounted within one-quarter inch of the liftarms on the bed, as shown in Fig. 336, B. This gives as near as possible a perpendicular pull on the cables. THIS IS THE MOST IMPORTANT POINT IN MOUNTING THE HOIST.

Second: The hoist should be mounted on the truck as close to the back of the seat or cab as possible, but this is not absolutely necessary, as the hoist can be mounted anywhere on the

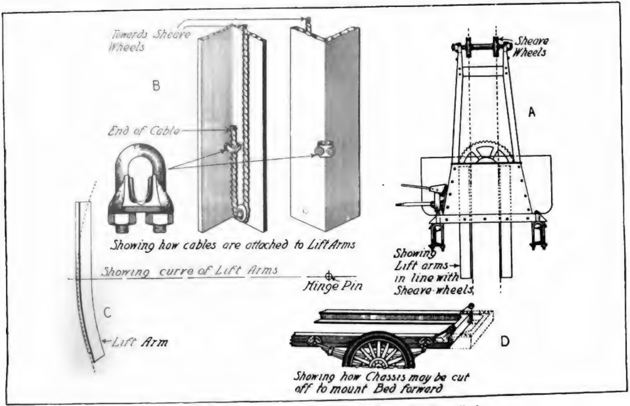

Towards Sheave Wheels
B
End of Cable
Showing how cables are attached to Lift Arms
Showing curve of Lift Arms
Hinge Pin
C
Lift Arm
Sheave Wheels
A
Showing Lift arms in line with Sheave-wheels
D
Showing how Chassis may be cut off to mount Bed forward

Fig. 335.—How Columbian Lightning Hoist is Installed.

frame as long as it is against the lift-arms on the bed. This means, then, that the bed must be hinged as far to the front as it can be placed. The best method is to mount the bed hinges at the rear spring clips on the truck, cutting off the chassis frame at this point and moving forward and re-attaching the end member of the chassis frame as shown in Fig. 335, D. The center of the bed should not be less than six inches forward of the center of the rear wheels to put the right proportion of the load on the rear axle. In some cases it may be found that there is interference to the lift-arms by the location of cross-beams and rods. In these cases it will be necessary to mount the hoist where there will be clearance for the lift-arms and cables.

Third: The lift-arms must be bent to the curve made by the end of the body in rising. Fig. 335, C, shows the method of finding the radius of the curve. This can be easily drawn on the floor to actual size, and by placing the arms on the curve it can be seen if they must be bent. The arms are furnished curved and in many cases will be found suitable. It would not matter if they were bent from one-half inch to one inch past the curve.

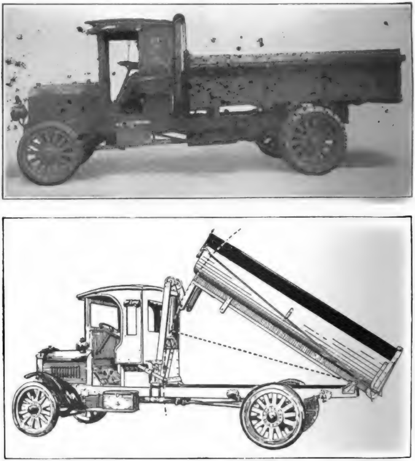
Fourth: The lift-arms must be placed on the bed so that they will be in the line with the sheave wheels at the top of the hoist, as shown in Fig. 335, A. One inch out of line, either in or out, would not make any difference.

Fifth: The lift-arms must be absolutely rigid. The end of the bed where the arms are attached must be strong enough so that the arms will not spring out when raising a load, and drag against the hoist. If this should occur the lift-arms can be made rigid by attaching additional braces connecting from them to the sills under the bed or against the bottom of the bed.

Sixth: The lift-arms should be placed on the bed with as much extension underneath as possible; in fact, they should have the same clearance from the ground as the lowest point of clearance on the truck.

Seventh: The cables must be attached to the lift-arms as shown at Fig. 335, B. An equal tension must be obtained on both cables. In attaching, tighten the clamps only enough to hold the cables. Then make the cables taut by operating the hoist slightly and allow the cable that may be taut to slip until the tension is equal on both. Then tighten securely. The clamps for the cable are placed on the arms with the nuts on the outside.

Operation of Wood Hydraulic Hoist.—Fig. 337 shows the various parts of the hoist mechanism, which is essentially identical in construction and operation with an hydraulic elevator, as applied to the F. W. D. truck. An oil pump at the base of the hoist draws oil from the top of the cylinder and forces it into the lower part, raising the piston, which in turn raises the body by means of cables running over sheave wheels. The oil pipe 4 which supplies the oil pump 5 is tapped in the cylinder 3 to provide an automatic stop for the piston.



Figs. 336A and B.—How Columbian Lightning Hoist is Installed Between Cab and Dumping Body.

Operating Instructions.—Fill the hoist cylinder to within one and one-half inches of the top through filling plug, Fig. 337, with ice machine oil. Be careful to strain the oil before filling, as grit and other foreign matter will injure the oil pump.

To Elevate Body.—Have engine running slowly and disengage engine clutch, moving clutch lever, Fig. 338, to "In" position.

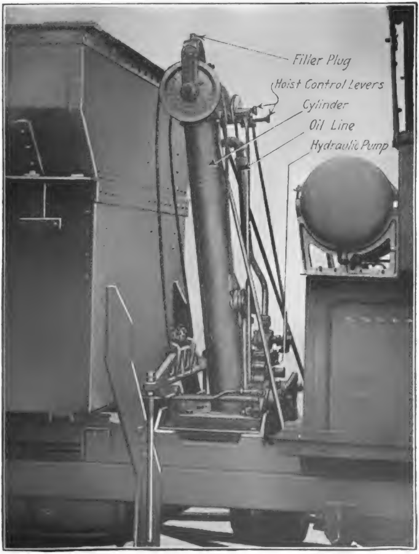

Filler Plug
Hoist Control Levers
Cylinder
Oil Line
Hydraulic Pump

Fig. 337.—**How Wood Hydraulic Hoist is Installed on F. W. D. Truck.**

Engage clutch and speed up the engine slightly. Move hoist control lever, Fig. 338, to "Raise" position, and piston will elevate the body.

To Hold Body.—When piston has reached the desired lift, move the control lever quickly to "Hold" position, as shown, especially when body is to be held in that position for some time or truck is to be moved with the body raised.

To Lower Body.—Move the control lever to the "Lower" position, Fig. 338. When body has reached the frame sills and cables are slack, move the control lever to the "Hold" position.

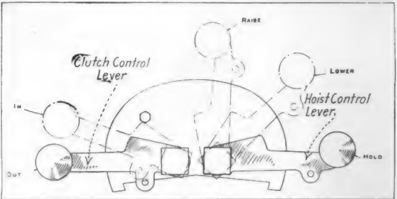


Fig. 338.—How to Operate the Wood Hydraulic Hoist.

Suggestions.—See that hoist clutch engages completely. Lubricate the hoist clutch shaft and sleeve wheels frequently with engine oil. Wash the chains and sprockets frequently with gasoline and lubricate with transmission oil "B." Never engage hoist clutch without first disengaging engine clutch. Keep oil line and connections tight to prevent leakage of oil and introduction of air into the system, which will cause foaming at the filling plug vent. Keep cylinder stuffing box tight. If the body is to be lowered with its load, do not allow it to descend too quickly. Grease the cables with graphite compound to prevent rusting.

Pierce-Arrow Hydraulic Hoist.—The following instructions apply only to trucks equipped with the Pierce-Arrow hydraulic hoist.

The hoisting arrangement consists of:

1. The rotary spur gear oil pump.
2. Seamless steel cylinder.

3. Piston and rod with sheave wheels.
4. Control mechanism.

The operation of this hoist is similar in action to that previously explained. The cylinder acts as the oil reservoir and in hoisting the pump draws oil from the top part of the cylinder and forces it into the lower part, thereby elevating the piston, which in turn lifts the body. When the body is fully elevated, three small poppet valves located in the piston come in contact

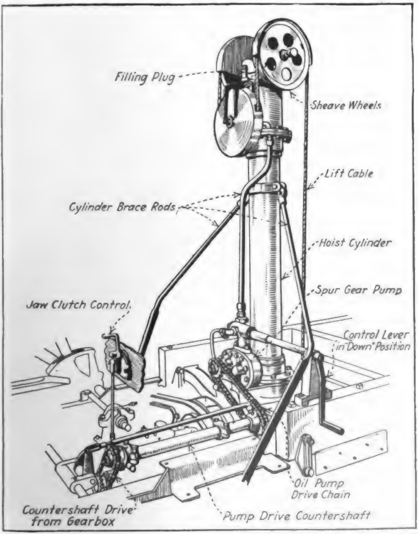

Filling Plug
Sheave Wheels
Lift Cable
Cylinder Brace Rods
Hoist Cylinder
Spur Gear Pump
Jaw Clutch Control
Control Lever in "Down" Position
Oil Pump Drive Chain
Countershaft Drive from Gearbox
Pump Drive Countershaft

Fig. 339.—Diagram Showing Construction and Control of Pierce-Arrow Hoist.

by Google

with a striker plate and cause the oil to by-pass automatically, stopping the body.

Fill hoist through filling plug, Fig. 339, within one-half inch of top with a good ice machine oil. It will hold about four gallons. In very hot weather, this oil may be a little too light and it may be necessary to use a medium engine cylinder oil. Take every precaution to see that oil is clean, as the smallest quantity of grit or dirt will seriously injure the pump. It is well to strain the oil through cheese cloth.

To Elevate Body.—Have the engine running; then take seat in truck after noting that the control lever is in the "hold" or horizontal position, Fig. 339. Then slow down the engine and depress the clutch to facilitate engagement of oil pump, drawing up jaw clutch handle until it remains up. The same operation releases body hooks. Then accelerate the engine slightly and move the control lever quickly to the "up" position, when the body will start to elevate.

To Hold Body.—If it is desired to hold the body up for any length of time, or to move the truck with the body elevated, move the control lever to the "hold" position. Caution should be exercised in maneuvering truck with body elevated not to start quickly or jerk it unnecessarily.

To Lower Body.—Move the control lever to the "down" position, Fig. 339, and after the body is down on the frame sills release the jaw clutch and move the control lever to the "hold" position.

Suggestions for the Care of Hoist.—1. Oil level should be one-half inch from top of hoist when the body is down. 2. Keep stuffing box on pump adjusted so that the oil cannot leak out. 3. Always have the by-pass handle in the "hold" or horizontal position when engaging jaw clutch. 4. To engage jaw clutch (which connects the oil pump with transmission) depress clutch pedal enough so that when drawing up on jaw clutch handle the jaws will be properly meshed, i.e., fully engaged when the jaw clutch handle is up. 5. The jaw clutch must be properly adjusted at all times to insure correct operation. 6. If the oil in the hoist had a tendency to foam and overflow through the filling plug vent hole, it is caused by a leak in the pipe or connections over the oil pump, thereby permitting air to be drawn in and churned up with the oil. 7. If it is desired to lower the body before all the load is discharged, care must be taken not to let the body descend too quickly. 8. Oil all moving parts of the hoist as well as the body hinges and tail-gate, and also apply grease to the cables to prevent rusting.

Angle of Slide.—An important consideration in the designing of dumping bodies is the angle of slide which means the minimum angle with the horizontal that material will move by its own weight or gravity attraction. The angle will vary with the nature of the material and the body construction, also the condition of the material. As will be seen by table below, the angle of slide for moist ashes is 36 degrees, because ashes in that condition hold together better than dry ashes, which will begin to slide at 33 degrees. Wet ashes will slide at 30 degrees, because the water acts as a lubricant to make the movement easier. An angle of inclination of 45 degrees will be sufficient for dumping almost any of the materials ordinarily handled in dump trucks.

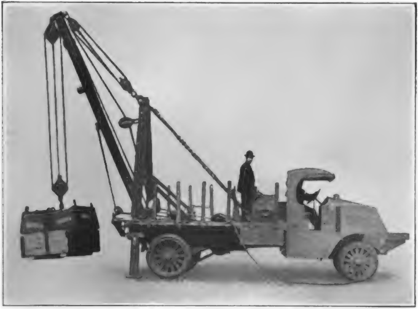


Fig. 340.—Mack A. C. Truck Fitted with Special Derrick.

Angle of Repose.—When material in the form of fine particles or small pieces is piled, there is a certain angle with the horizontal that cannot be exceeded because the material will slide down if that angle is exceeded. This also varies with the character of material and will vary from 25 to 40 degrees for substances usually stored in piles.

ANGLES OF SLIDE OF VARIOUS MATERIALS

Name of Material	Angle of Slide in Degrees	Name of Material	Angle of Slide in Degrees
Ashes, dry	33	Earth, loose	28
Ashes, moist	36	Earth, packed	50
Ashes, wet	30	Garbage	30
Asphalt	45	Gravel	40
Brick	40	Ore	30
Cinders, dry	33	Ore, run-of-the-mine	35—40
Cinders, moist	34	Rubble	45
Cinders, wet	31	Sand, dry	40
Cinders and clay	30	Sand, No. 2. & broken stone	27
Clay	45	Shingles	40
Coal, anthracite	25	Stone	30
Coal, bituminous	30	Stone, broken	27
Coke	23	Stone, crushed	30
Concrete	30	Stone, run-of-the-mine	35—40

Portable Cranes and Derricks.—In certain classes of contracting work and around industrial plants, it is necessary to have readily portable lifting cranes and derricks for handling heavy objects such as blocks of stone, large castings, etc., either with the object of moving them from place to place or for assisting in the loading or unloading of freight cars or trucks not equipped with special hoisting facilities. The derrick shown at Fig. 340 is mounted on a Mack chassis and was intended for use by the Army Engineer Corps. The derrick mechanism which is shown under test in the illustration has a capacity for lifting six tons easily, the load being raised by a block and tackle arrangement attached to the boom of the derrick which may also be raised as desired by the motor driven winch or windlass carried behind the driver's seat and operated by a power take-off from the motor truck power plant.

The arrangement shown at Fig. 341 is mounted on a Winther truck chassis and consists of a complete power plant with boom, mounted on a counterbalance platform which can swing around almost a complete circle. While the derrick may be used for lifting purposes only having a range of almost a complete circle around the truck, it is shown in the illustration with a clam shell or grab bucket used for dredging and filling purposes. This may be used for unloading any material that can be handled by the bucket and transferring it to any point desired or to another truck. A gasoline engine entirely independent of that utilized in driving the truck is employed to operate the windlass that controls the movement of the derrick boom as well as raising the bucket. By the use of gears, this engine also serves to turn the entire platform around as desired on the large circular rack attached to the truck chassis. The reason a separate engine is used rather than using the truck power plant is that for such work of the nature that this truck is designed to do, it would not be economical to run the motor truck power plant throttle down, as a simpler and less expensive engine of a few horse power suffices to do the work. This engine is more economical of fuel and as it is a special heavy duty type it saves the wear and tear on the more expensive motor truck power plant.

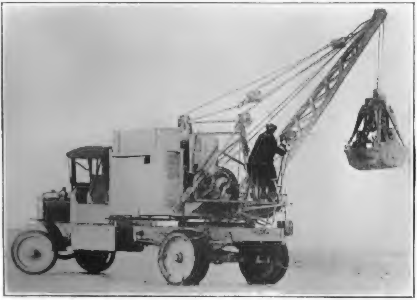


Fig. 341.—Winther Truck Equipped with Special Derrick.

Fire Department Wrecking Truck.—The illustration at Fig. 342 shows the wrecking truck that is in the service of the New York Fire Department that is carried on a Mack 5½-ton chassis. This is a repair truck, that is used for salvaging wrecked fire fighting equipment. The traveling telpher, which is provided with a block and fall, can be used for bringing in apparatus even if one of the wheels or axles is broken, or if it has collided with some other vehicle and is so badly damaged that it could not be moved easily by ordinary means. Another use is to pull wagons, etc., out of manholes or cave-ins, replacing derailed trolley cars, and for the usual run of wrecking and salvage duty that falls to the lot of a fire department in any large city. The sides of the body are composed of substantial work benches, provided with compartments in which not only fire fighting equipment is carried, but also the necessary tools for making emergency repairs to damaged apparatus. Each work bench is provided with a substantial vise. The rear of the chassis is equipped with a towing hook and a pair of substantial skids is carried under the floor. When the lifting telpher is in use to handle a heavy object a pair of screw jacks carried by the rear of the chassis are dropped down and adjusted to support the

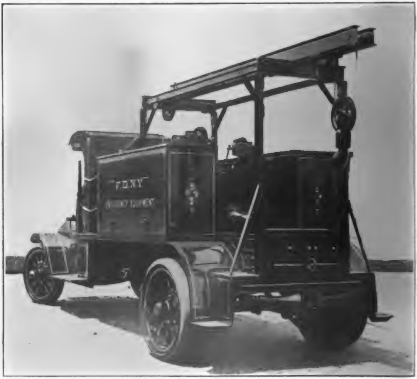


Fig. 342.—Special Wrecking Truck Used by New York City Fire Department.

rear end and take some of the load off of the truck springs and tires. When the jacks are down, a rigid platform is obtained. The chain block is operated by a winch, which is in turn driven by the engine. The uses for an emergency truck of this character are such as to demand exceptionally strong construction without having so much weight as to impair the mobility of the outfit.

A small electric industrial truck used by the Buda Engine Company for the transfer of their product around the plant is

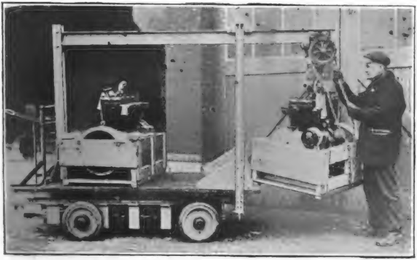


Fig. 342A.—Special Crane Designed for Small Industrial Truck.

shown at Fig. 342A. This uses a crane operating on the same principle as the larger capacity one shown at Fig. 342. Its use and advantages are apparent.

Motor Driven Fire Apparatus.—One of the applications to which the motor truck chassis lends itself particularly well is in connection with various forms of bodies to carry fire fighting equipment. The speed of the modern motor truck makes it possible to greatly exceed the best time made by horse-drawn apparatus, as the lighter combination wagons are capable of traveling at the rate of nearly a mile a minute, while the heaviest apparatus can make three times the speed of the old horse-drawn equipment.

When used for fire department purposes a motor truck not only receives the best of care but it is used so little that it will practically never wear out. The advantages of motor-drawn equipment over the animal drawn from a viewpoint of rapid service. more economical maintenance and more sanitary living conditions for the fireman, who must live in the same house that garages the equipment, are apparent to any one who has seen this apparatus in service or who is at all familiar with conditions that obtain in fire department work.

It is not only in large cities that motor fire trucks prove their

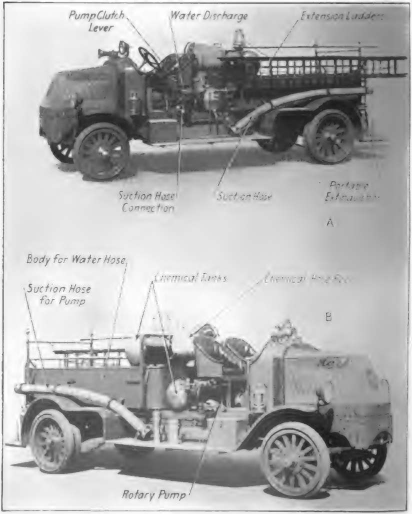

Pump Clutch Lever
Water Discharge
Extension Ladders
Suction Hose Connection
Suction Hose
Portable Extinguisher
A
Body for Water Hose
Suction Hose for Pump
Chemical Tanks
Chemical Hose Box
B
Rotary Pump

Fig. 343.—Combination Fire Apparatus Mounted on Mack A. C. Truck Chassis.

worth, as many small communities that formerly could not afford the luxury of a fire department because of the maintenance expense are now able to purchase and maintain popular low-priced chassis fitted with a practical fire fighter's equipment that can be easily handled by a couple of men and that will reach a fire so quick that most of them may be extinguished before much damage is done.

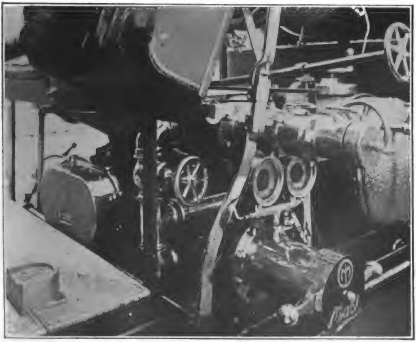


Fig. 344.—How Pump is Installed in Mack Combination Engine.

Tractors Used for Long Apparatus.—Very heavy and long pieces of apparatus, such as water towers and hook-and-ladder trucks are usually hauled by tractors of either the two-wheel or four-wheel forms. When a two-wheel tractor is used it is usually built into the apparatus, as it has all of the power generating, transmitting and control elements incorporated in a compact unit that may be attached to the existing horse-drawn equipment without expensive machine work. The use of a tractor makes it possible to retain old equipment that is still in good condition, such as steam fire engines, and yet obtain the advantages of the ease of control and mobility of motor traction.

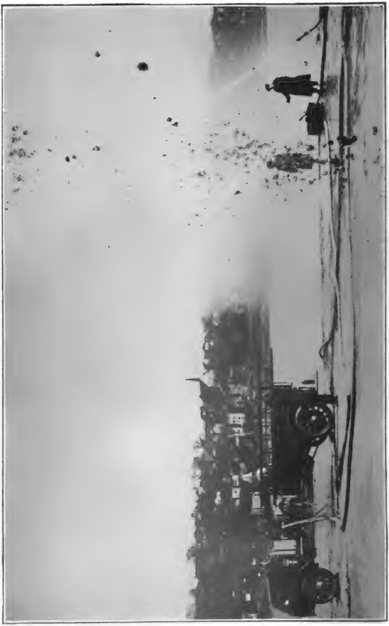


Fig. 345.—The Mack Combination Apparatus Making Pumping Tests.

Combination Apparatus.—The outfit shown at Fig. 343, A and B is a combination apparatus mounted on a Mack chassis. This not only includes the usual features of the combination hose and chemical wagon but has incorporated in the mechanism a special form of rotary fire pump. It will be evident that this is a complete fire fighting unit that is capable of throwing two or more strong streams of water on any fire that the chemical tank equipment is not able to cope with. The fire pump is carried under the driver's seat and is fitted with driving connections so that it can be operated from the truck power plant. The method of installing this pump is clearly shown at Fig. 344 and its use during a test when throwing two streams of water is shown at Fig. 345. The chemical tank is carried immediately back of the water pump and the chemical hose is supported by a rotary reel directly over the tank. The body, which is of the box form, carries the water hose folded in the usual manner so that it may be readily played out from the hydrant to the burning structure. Extension ladders are carried and the usual fire fighting equipment of lanterns, axes, pike poles, portable extinguishers, etc., are easily accommodated in the commodious body.

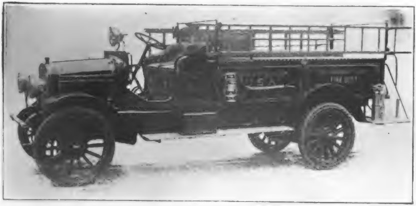


Fig. 346.—Brockway Truck Chassis with "Straight Hose" Equipment.

The equipment shown at Fig. 346 is installed on a Brockway chassis and is known as "Straight Hose," the body having a capacity of one thousand feet 2½-inch fire hose and equipment consisting of electric lights, generator, storage battery, with two electric headlights, two dash lights, swivel searchlight and tail light; one 20-foot extension ladder, one 12-foot roof ladder, pike pole, pick back-fire axes, crowbar, two fire department lanterns, two three-gallon hand extinguishers, two play pipe holders and one mesh basket for coats, hats, etc. This type was adopted by the Government for installation at their several powder plants.

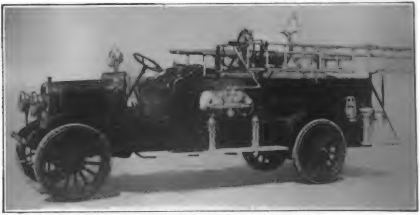


Fig. 347.—Brockway Double Tank Combination Apparatus.

The Type B Brockway Four-Cylinder Double Tank Combination Body, as shown at Fig. 347, has a capacity of one thousand feet of 2½-inch fire hose. Equipment consists of electric starter, two electric head, two dash, one swivel search and one tail light, two 35-gallon nickel-plated chemical tanks, with 200 feet of ¾-inch chemical hose on reel, one 20-foot extension ladder, one roof ladder, two fire lanterns, one pick back-fire axe, one crowbar, two tool boxes, two play pipe holders, one locomotive bell,

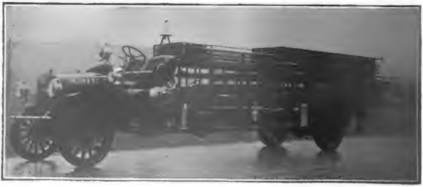


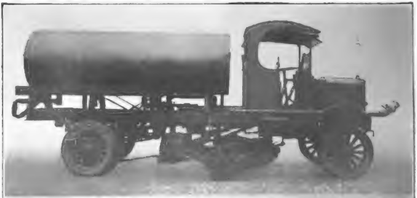
Fig. 348.—Brockway Type A Service Truck.

whistle on exhaust, one shut-off nozzle, two nozzle tips, two hose spanners, one soda bag, two acid receptacles and receptacle holder; filling cap wrench. This particular truck was installed in the service of the Winchester Repeating Arms Company at their plant in New Haven, Connecticut.

The outfit shown at Fig. 348 is the Brockway Type A Four-Cylinder Service Truck. It is equipped with a Presto tank, two headlights and swivel searchlight, with oil dash and tail light. Ladder equipment as follows: One 50-foot rapid hoist rope and pulley extension to extend 50 feet with supporting poles; one 35-foot rapid hoist rope and pulley extension to extend 35 feet; one 28-foot single ladder, one 24-foot single ladder, one 20-foot single ladder, one 16-foot roof ladder, one 12-foot roof ladder, two 25-foot single side ladders. Miscellaneous tools and equipment: 2 Crotch poles, 4 fire department axes, 6 pike poles, assorted lengths; 2 wall picks, 2 crowbars, 2 shovels, 1 wire cutter, 1 door opener, one tin roof cutter, 2 pitchforks, 2 No. 2 Babcock fire extinguishers, 4 fire department lanterns, one wire basket 14" x 30" x 6' in rear of driver's seat for tools, etc.; one tool box. Chemical Equipment: Chemical tank, 40 gallons capacity; chemical hose basket; chemical hose, 200 feet ¾-inch special 4-ply, coupled with heavy brass couplings; one shut-off nozzle, two nozzle tips, two hose spanners, one soda bag, two acid receptacles, with lifers; one acid receptacle holder, filling cap wrench, two hand extinguishers.

Motor Trucks for Municipal Use.—Motor trucks are rapidly displacing other means of conveyance in the sanitary and street cleaning department of all of our large cities and many of the smaller ones. Fitted with dump bodies, motor trucks are ideal for handling ashes, garbage, and other refuse economically and quickly. Fitted with special trunk bodies, they may be used for sprinkling the roads, washing the streets and similar uses. The truck shown at Fig. 349 is a street washing machine fitted to a Brockway chassis. A large tank to carry the water is mounted above the chassis, while a "squeegee," or washing roller, carried by a special framework is supported below the truck frame. This roller is rotated by sprocket and chain connection with the rear wheels. It may be raised or lowered, as desired to suit the various types of pavement, and may be raised entirely clear so the truck will perform the duties of a simple watering cart, as shown at Fig. 350. Pipes extend from the tank to special sprinkler heads, each side of the front end of the chassis frame, which are so designed as to sprinkle the entire width of the street on one trip. The ordinary form of horse-drawn equipment has sprinkler heads that will only wet down half of the street at a time. Not only is it possible to carry more water, owing to the size of the tank, but the work may be done at twice or three times the speed possible with horse-drawn tank wagons.

The combination body, shown at Fig. 351, is used by the city of Perth Amboy in its street-cleaning department and comprises the usual form of hydraulic dump body and a detachable tank that may be connected to sprinkler heads at the rear of



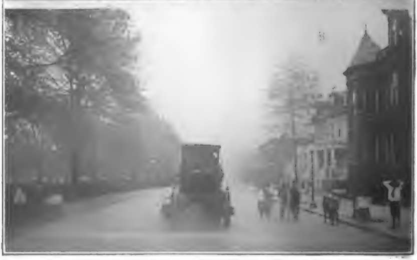


Fig. 349.—View at A Shows Combined Watering Cart and Street Washer.

Fig. 350.—The View at B Shows Use of Apparatus as a Watering Cart.

the chassis. The tank is provided with two substantial lifting bolts, one at each end, so that it may be lifted out of the body when it is desired to haul materials instead of watering or oiling the streets. The combination shown is an especially practical one, as it enables a small municipality to utilize its motor equipment to the best advantage and reduces the investment necessary if single purpose equipment is used.

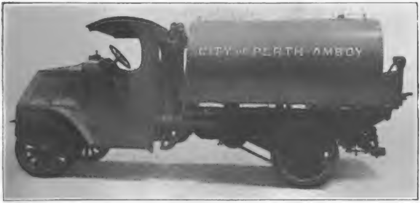


Fig. 351.—**Mack Chassis with Combination Body Equipment Useful for Municipalities.**

There is practically no limit to the character of material that is hauled by motor trucks. A road roller is not a very fast

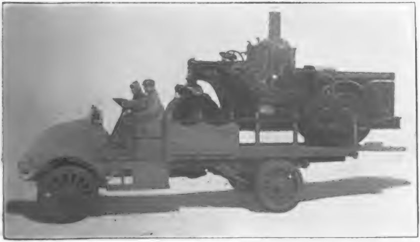


Fig. 352.—**Kelly-Springfield Truck Employed for Hauling Road Roller.**

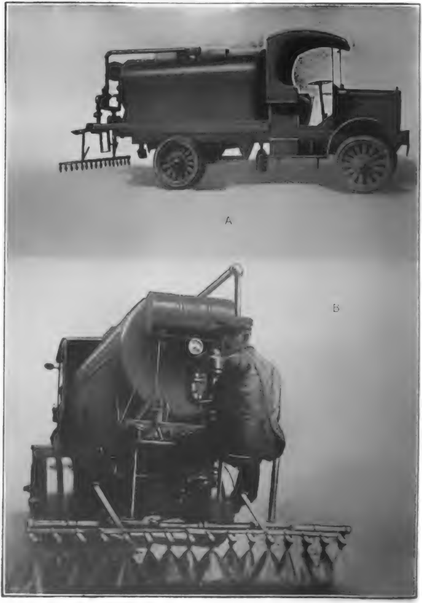


Fig. 353.—Brockway Chassis with Oil Distributing Body in Place.

moving piece of machinery. The usual speed being about four miles an hour for a heavy roller and six miles for a light one. Considerable time would be consumed in moving a road roller from one part of a city to another if it were not for the motor

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truck. In the illustration at Fig. 352, the hauling capacity of a standard 3½-ton Kelly truck is shown as it is loaded with a road roller of substantial proportions. The superior speed and easier control of the truck makes it possible to bring the road roller from one job to another without much loss of time.

When the steel contractor's dump body is removed from the Brockway chassis the 600-gallon tank, with oil distributor, may be mounted in its place, in which manner one chassis serves the purpose for a Dump Truck as well as an oil distributor, making a very economical combination. The oil distributor is connected with the power head as described above, thereby giving proper pressure for distributing heavy oil and has proven itself an efficient and highly satisfactory truck for State, county and municipal work in the building and maintenance of roads. It is clearly shown at Fig. 353, A and B.

Truck-driven Plow.—A truck equipped with a snow-plow has been used with a great deal of satisfaction to break tracks in heavy snow in the highways in a Montana county, so that traffic could be maintained practically without cessation. This plow was improvised by the country engineer and a five-ton truck was adapted at low cost as shown at Fig. 354. This equipment, once built, can be used for a long period of time, and the expense, carried over several years, is comparatively small.

In this instance the truck front spring horns were fitted with a bumper, to which was bolted a timber six inches square. The plow was built with the side boards centered and extending to either side to cut a patch approximately eight feet wide. The frame of the plow was heavy timber and side boards were sheathed with a sheet metal with the lower edges reinforced with quarter-inch strap steel.

At the apex of the plow was placed a perpendicular beam six inches square. The rear of the plow frame was hinged on the cross timber bolted to the bumper. From the top of the upright member at the nose of the plow a block tackle was carried back over the truck cab to an eye-bolt attached to a cross-frame member at the rear. The tackle was elevated above the cab roof by a pair of diagonals bolted to the sides of the body and carrying a large, deeply grooved free pulley to prevent the rope chafing. With this tackle, the height of the plow could be regulated to make the cut in the snow any depth desired.

Across the rear of the truck was fastened a timber six inches

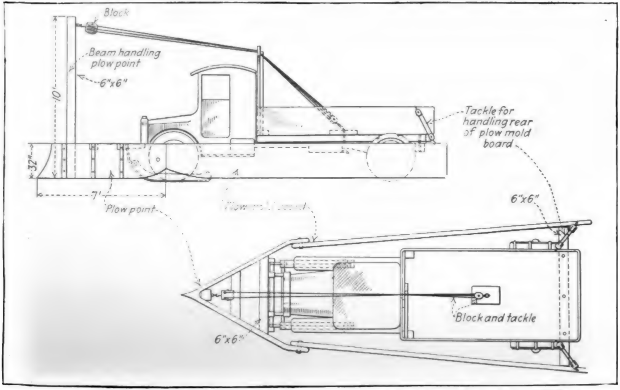
Block
Beam handling plow point
6"x6"
10'
32"
7'
Plow point
Plow mold board
Tackle for handling rear of plow mold board
6"x6"
Block and tackle
6"x6"

Fig. 354.—Special Snowplow Adapted for Mounting on Truck to Clear Snow-Covered Roads.

square with diagonal braces extending to the side members of the chassis. From the ends of this timber spreader boards extend forward to and inside the side boards of the plow, where they are pivoted, so that the plow can be elevated or lowered. The lower rear corners of the side boards and the lower forward corners of the spreader boards are rounded to obtain clearance. The rear wheels are equipped with chains. The front wheels are mounted on a pair of runners clamped to them, which can be moved by the steering gear, and the runners are shod with quarter-round rods to prevent side slip.

The plow will weigh approximately 1,000 pounds, and the truck so equipped not far from six tons. With the truck body weighted traction can always be obtainable. With the outfit many miles of deep snow can be cleared in a day and highways kept in reasonably passable condition, no matter what the snowfall. The accompanying diagrams illustrate the general plan of construction. This equipment can be constructed with easily obtainable tools and materials and can be quickly rigged when wanted.

Typical Bus Body.—The "Speed 'Bus" body, made by Graham Brothers, Evansville, Indiana, is 6 feet 2 inches high inside; width of aisle is 2 feet 9 inches. Outside body dimensions: Width 6 feet 1 inch, height 6 feet 4 inches, length 14 feet. Seats are 18 inches high and 16 inches deep; spring-cushioned seats and padded backs, upholstered in imitation leather. Driver's seat also with upholstered back; battery and tool compartment underneath; gasoline compartment at left.

The vestibule door is operated by a lever from driver's seat. This door extends to the bottom step, which is 14 inches from the ground. The second step is 8½ inches high. The floor is 8½ inches above the second step. The door is 24½ inches wide and 6 feet 6 inches high. The rear door is 5 feet 3 inches high, 21 inches wide, with an outside step. The windows consist of movable lower sashes, 26 by 16 inches, and stationary upper sashes, 26 by 12 inches. Sliding panel for arm signaling to the left of driver. The windshield is one-piece ventilating type, 33 by 21 inches, and can be swung either in or out. The electric equipment includes four frosted glass dome lights, signal buzzer, eight signal buttons conveniently located.

Floor sills, uprights, deck ribs, door and window sashes and windshield frame are all made of carefully selected and thoroughly seasoned hardwood. Three of the truss through-bolts on each side extend through angles riveted to the motor truck frame, firmly securing the 'bus body to the chassis. No body bolts run through the flanges, of the motor truck frame itself.

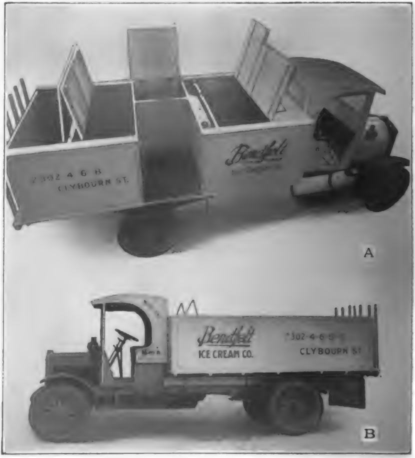

Fig. 355.—Special Body for Moving Ice Cream is a Good Example of Body Design to Meet Individual Requirements.

The wheel housings permit an extra width of body and a low floor accessible in three easy steps. The body is intended for a 1½-ton capacity chassis.

Special Duty Motor Trucks.—Each line of business has peculiar local conditions to meet that can be solved to best advantage by the design especially built motor truck bodies. It will be apparent that it would not be practical or desirable to have an

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infinite variety of chassis forms, and fortunately by the equipment of a special body a standard chassis design may be made to serve a wide variety of industrial requirements. It is not possible in a work of this character to show the infinite variety of special bodies that have been designed for application to industrial transportation. Typical examples have been selected, however, that are of interest to all and that cannot fail to offer suggestions that will be valuable to anyone interested in motor hauling.

The special type of body shown at Fig. 355, A and B, has been designed to meet the peculiar requirements of an ice-cream manufacturer and is installed on various types of Federal chassis. That at A is fitted to a solid tired truck, while the form at B is equipped with pneumatic tires to permit of more rapid delivery. As will be noticed from the top view at A, special compartments are provided for carrying the ice-cream can, ice and rock salt. The platform is designed so that the cans may be easily lifted out and the refrigeration may be maintained by an attendant while the goods are in transit. The compartments are provided with hinged covers and all leakage that results from melting of the ice is carried clear of the chassis by special conductors and drainpipes, so that the water will not drip down on any parts of the mechanism.

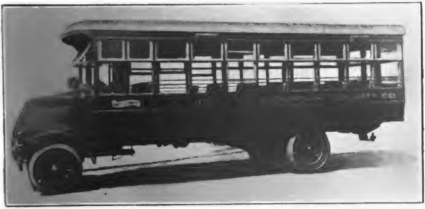

Fig. 356.—Large Capacity Bus Body on Mack 5½-Ton Capacity Chassis.

A good example of the use of the motor truck chassis to passenger carrying work is given at Fig. 356. This is a large 'bus fitted to a 5½-ton Mack chassis which is operated by the

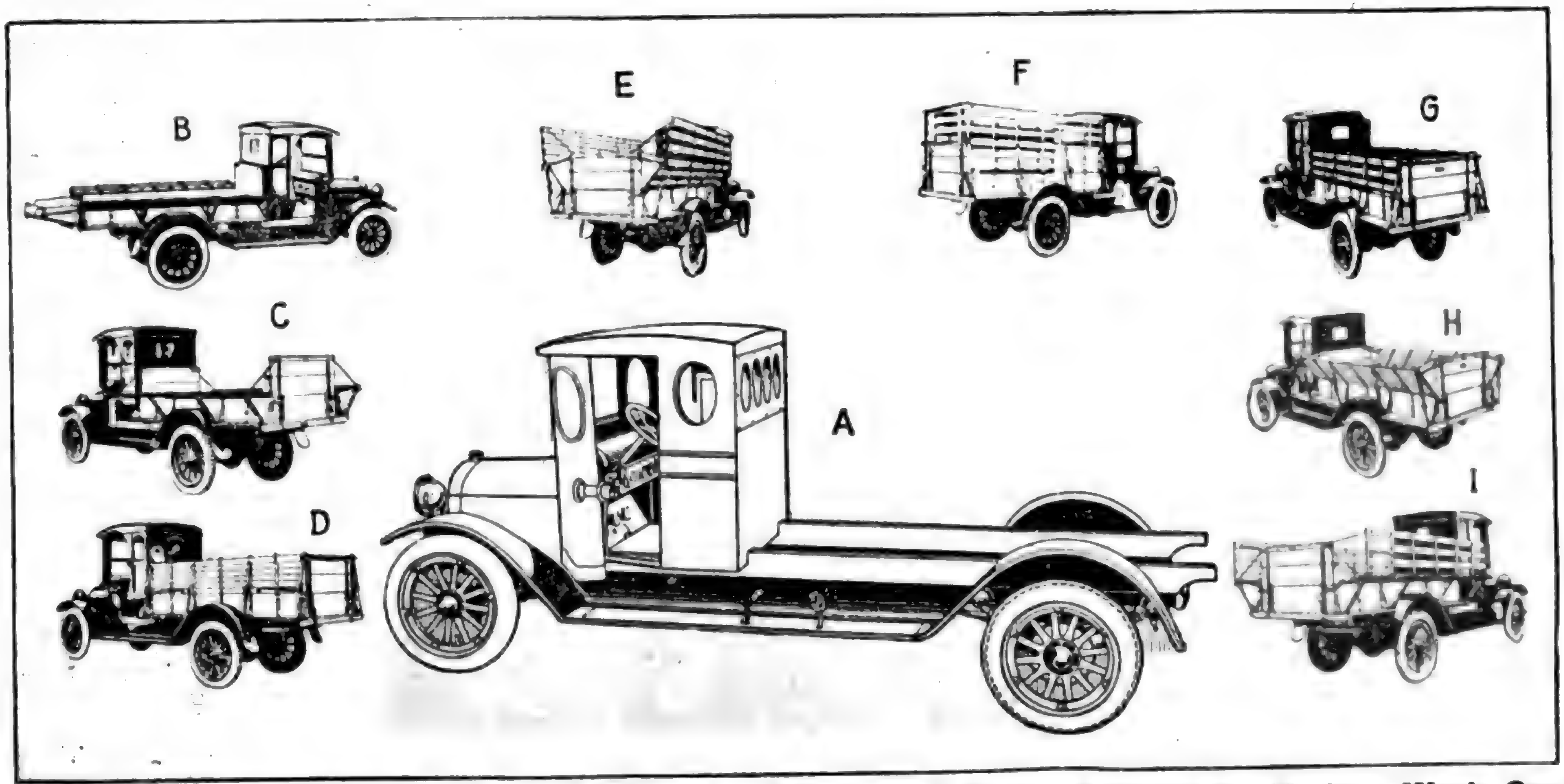

Fig. 357.—Chassis of the Reo Speed Wagon and Variety of Bodies Suitable for Various Work One Combination Body Can Be Converted Into.

Suburban Transit Company, Plainfield, N. J. The 'bus body is equipped with the usual form of seats which are ranged in rows down each side of the body with an aisle between. The windows may be raised to allow cooling breezes to circulate through the body in warm weather and may be lowered in inclement weather. Eighteen double seats are provided, which give a capacity of thirty-six passengers. The 'bus is a pay-as-you-enter type, the only means of ingress or egress being through a small door opposite the driver, who also acts as conductor. This 'bus is equipped with a number of refinements, such as electric light, exhaust heat, etc., and every effort has been made to secure easy riding qualities by the use of Westinghouse air springs and Sewell cushion wheels.

Combination Bodies.—There has been considerable development noted of late in bodies composed of a number of units that may be placed in different relations to each other to obtain various body forms adapted for a wide range of work. A notable combination body of this form is the farm body designed for the Reo Speed Wagon Chassis, which is shown at Fig. 357, A. In this, the same cab is used with all of the varying body combinations. The body is installed on the longitudinal wooden frame sills and by the use of folding sides, extension tail-gate and racks, it may be utilized for hauling everything used or produced on a farm. As shown at B, the tail-gate is lowered and the rack sides are used as flare boards. This makes it possible to carry various kinds of produce in bags or bales without any difficulty. The tail-gate permits lifting heavy bales or sacks in place without exertion of much effort. When the rack sides are folded up against the tail-gate, as shown at D, a box body is obtained. With flare sides extended and tail-gate extensions folded out a commodious rack body for carrying livestock is secured. A modification of the rack body for the same purpose which has straight sides is outlined at F. At G, the upper part of the rack sides are folded over to form a roof for the box body so that smaller domestic animals and fowl may be transported. With the arrangement of the flare boards and tail-gate, as shown at H, a body that is well adapted for carrying corn, potatoes, turnips, cabbage, and similar vegetables in bulk, manure or ensilage and numerous other materials that will suggest themselves to the practical farmer. With the sides extended as shown at I, a very good hay wagon is obtained. The

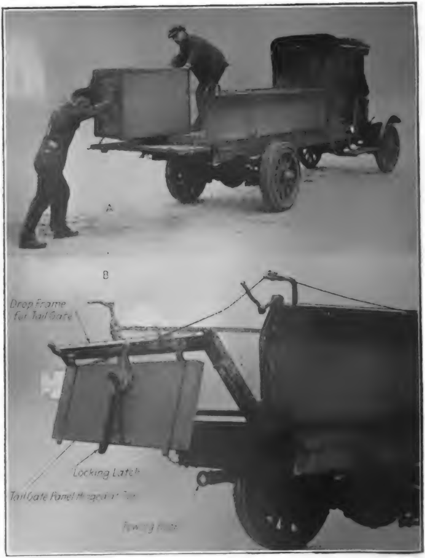
A
B
Drop Frame for Tail Gate
Locking Latch
Tail Gate Panel Hinged
Towing Hook

Fig. 358.—Combination Express and Dump Body Fitted to Federal Chassis.

changes are easily made, as all of the combinations shown are produced by lengthening or shortening the bracing levers at the sides of the body. If the boards comprising a solid side are spread apart, one will easily obtain a rack side, and if the brace members are properly jointed it will be evident that all of the combinations shown may be obtained without difficulty and a body type adapted for the requirements for the work to be done is secured at short notice.

Combination Express and Dump Body.—An exceptionally fine Federal truck was delivered recently to Chas. S. Wheeler for use on his vast estate at McCloud, California. The Federal is equipped with a combination body that renders the truck useful for a number of different kinds of work. The demands of the owner were to design a combination express body, dump body, which was to be removable, so that the flat bed of the truck could be used for hauling large and cumbersome commodities upon the large estate of the owner.

The uniqueness of the special body and truck caused much attention on the part of truck owners as well as body builders, owing to its unusual design and practicability in performing those duties for which it was designed. In the opinion of those who have examined it, it is a very practical combination body. The express or delivery body shown at Fig. 358, equipped with a drop tail-gate, is zinc plated, steel lined and constructed to be leak-proof, and is readily adaptable for loose materials such as sand, gravel, etc., or for the purpose of hauling merchandise.

The body is so constructed that during a demonstration given a few days ago, it was removed from the chassis and rolled upon a special built receiving stand in less than four minutes. as shown at Fig. 359, A and B. The frame of the truck is equipped with rollers so that the body can easily be slid off the truck chassis onto the receiving stand by two men. When the body has been removed from the truck chassis the specially constructed flat bed can be used to haul logs or other large and cumbersome articles that it would otherwise not be possible to handle, as shown at Fig. 359, C.

One of the most novel features of this specially designed truck is that when the body is removed, the under body is equipped with roller and skid sockets on either side and rear, and to permit of the handling of heavy materials which are rolled or skidded over these rollers to loader position on the truck. The heavy materials, such as logs, etc., are automatically lifted or drawn into place on the truck by its own motive power through the use of the hoist gables operating from the motor.

The truck can also be used for road work, being equipped with a special hydraulic hoist raising the body to an elevated dump body position, permitting loose materials used for road work to be easily slid out of the dump body and spread.

The acquisition of the specially double-acting tail-gate shown at Fig. 358, B, which consists of a drop tail-gate into which has

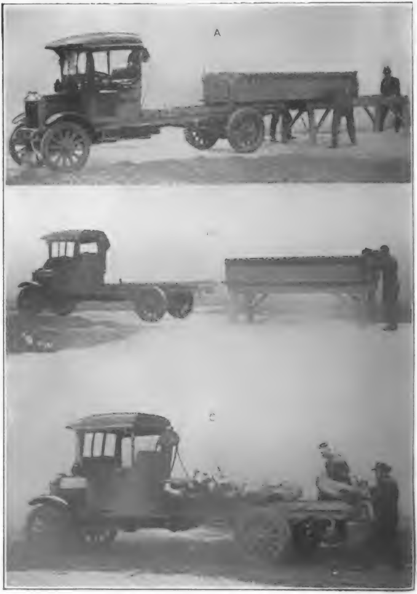

Fig. 359.—Combination Dump and Platform Body. The Dump Body May Be Removed, as at A and B. Leaving the Platform Clear, as at C.

been built another gate that is used for spreading when the body is elevated for dumping purposes, is likewise a novel and unusual feature. The latter gate is operated from the driver's seat. This Federal is likewise equipped with a specially designed spring draw bar for tractor use, eliminating the undue shock and stress upon the truck when used with a trailer.

Motor trucks have taken such an important part in solving the transportation and haulage problems that confront the business man to-day, that the various makers are often being called upon to design special equipment for use in connection with the motor truck. The engineering and technical departments for this purpose have long been a feature of the leading organizations and have been responsible to a great extent through the unique designs and construction of bodies turned out for the many different special uses to which motor trucks are being put.

Special Truck for Arc Welding.—Once more the motor truck comes to the front in solving one of the problems of industry. This time it is a Packard truck equipped to do arc welding, both marine and land work, and its equipment is illustrated at Figs. 360, A and B. With the past three years of war as an incentive, great strides have been made in the art of welding iron and steel and naturally the use of welding for joining materials has increased considerably. The electric arc method of welding has been developed to a point where satisfactory welds can be made of cast iron, wrought iron and various grades of steel.

The electric arc process is comparatively simple, easy to manipulate, very rapid, and compares favorably in cost to other methods of welding. The metallic electrode method of arc welding is usually employed, as this system gives a strong and durable weld. By this method it has been found that welds can usually be made with a tensile strength of from 80 to 100 per cent. of the strength of the original stock, and when the building up method of welding is used, it is usually possible to make the weld stronger than the original section as far as the actual space welded.

Electric welding has been used largely for repairing boilers, steel plate work, and broken parts of cast iron or steel; but recently, with the advance of knowledge of electric arc welding, it is being used very largely in the fabrication of new iron and steel parts. For filling in of defective castings and for the reclamation of the junk pile, it is customary to install a special generator having the proper electric characteristics. In a great many cases, however, it is impossible to bring the work to the welding machine and, consequently, the welding plant must be set up near the location of the arc to be welded. This has led to the construction of barges containing welding equipment for marine work, and eventually to an automobile truck, for land and marine work. This truck can be quickly run to any desired place where electric welding is to be done.

In selecting a truck for this work, the Covic Electric Company decided to use a 5-ton Packard chassis, because this was considered the sturdiest and best adapted truck, after carefully con-

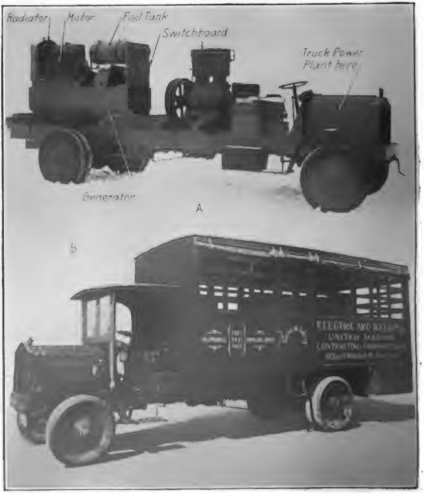

Fig. 360.—Complete Arc Welding Set Installed on a Packard Truck.

sidering various other makes of trucks. There is mounted on this truck first of all, a gas-kerosene engine driven arc welding machine large enough to supply power for two operators. The arc welding machine was designed and built by the Covic Electric Company. There is also mounted on the machine and driven from the Packard motor, a 90-foot air compressor to supply compressed air for pneumatic hammers and tools which are used in preparing parts to be welded and in finishing off the completed weld.

The horsepower required to operate this compressor is approximately 20 h.p. at 250 r.p.m. A special transmission was designed by this company in order that the power may be transmitted from their drive-shaft to the compressor. A Morse chain is used to transmit the power from the transmission to the compressor. This transmission is so constructed that it gives a reduction ratio of 4 to 1. The machine is enclosed by a large roomy body of special design which gives ample space for the operating of the machine and the carrying of supplies.

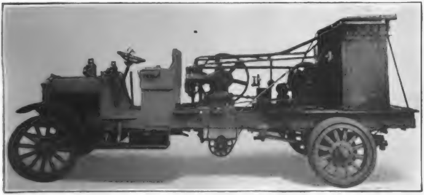

Fig. 361.—Outfit for Testing Casing Head Gas Mounted on Truck Chassis.

In addition to the above, the truck has been equipped with everything possible for the convenience of the operators. Among these things are two reels carrying 1,500 feet of welding leads and a spare tank for 40 gallons of fuel, and a 25-gallon tank for lubricating oil; also two larger tanks for air receivers, which will hold a supply of compressed air. The truck is also equipped with a work-bench with the necessary equipment, which will be found necessary for work to be done on such jobs. The body is electric lighted throughout, the source of the supply being taken from the generator. This special equipment was installed under the supervision of Mr. Charles S. Lyon, Special Equipment Engineer of the Packard Motor Car Company of New York.

Outfit for Testing Casing Head Gas.—The making of physical tests of casing head gas for determining the amount of gasoline contained in the gas is quite a job, but the Frick-Reid Supply Company of Tulsa, Okla., have solved this problem in a unique way. They have mounted a special machine made by themselves at a cost of approximately $3,500, upon a two-ton Federal truck chassis as illustrated herewith at Fig. 361.

It would take quite a lengthy article indeed to fully describe the adverse conditions which have been imposed upon this truck in the matter of getting over bad country, as it is necessary for it to be taken to within 11 to 30 feet of each well, which in some cases seems to be a matter almost impossible, but it has never yet failed. In making these tests the truck is backed up to the well where the testing plant can be attached in an instant. It requires from 6 to 12 minutes to complete a test on a well. The machinery weighs about 4,000 pounds and is one of the most efficient gas testing machines that has ever been manufactured.

The gas is taken in through an inverted Tobey meter into the scrubber tank, thence to the low stage side of the compressor, discharging into the 130 feet of ¾-inch coils to the low stage accumulator tank; thence to the suction of the high stage side and through 260 inches of high stage coils, discharging into the high stage accumulator. The compressor is a 2-stage Blaisdell having a capacity of 24 cubic feet of gas per minute at 250 or 300 pounds pressure on the high stage side.

The coils are arranged so that either or all can be removed, being connected on admission and discharge ends through the means of headers, with high-pressure flanged ammonia valves, which makes it possible for the operator to use as much or as little cooling capacity as is necessary to obtain the best results.

The machine is also equipped with thermometers located in the suction and discharge lines of both stages in order to determine the characteristic temperatures of the gas in the stages of compression and in leaving the accumulators. The compressor is cooled by means of a small centrifugal pump, taking the water from the coil tank and then returning it. Of course, the machine is operated entirely by the truck motor, the power take-off being mounted on the transmission.

Motor Truck Pipe Hauling Body.—One of the drawbacks to motor truck hauling equipment in the plumbing and engineering trade has been the difficulty experienced in handling piping—especially long pipes, as heretofore no provision has been made for effectively carrying such material. Loaded in an ordinary truck body, long piping overhangs far over the rear of the truck, striking the ground when the truck jolts over bumps, with the rear ends often trailing. And at the best, piping is difficult to handle, as it has a tendency to jounce about and interferes with loading or unloading other materials.

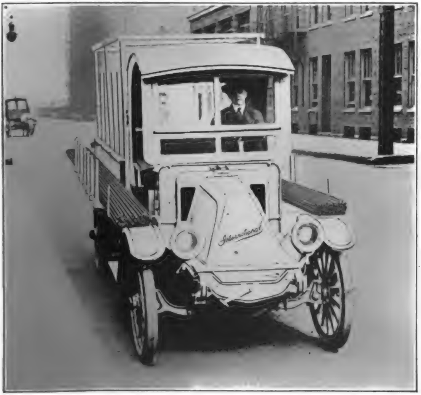

Fig. 362.—I. H. C. Truck with Special Body Racks for Carrying Pipe.

The Dodge Sales Engineering Company, Chicago, have satisfactorily solved their pipe hauling problem by equipping their International Harvester motor truck with a special body having side racks for receiving pipes, as may be noted from the illustration shown at Fig. 362. Brackets on either side of the truck just in front of the dash permit of carrying piping extending the full length of the truck without trailing or inconvenience. The body proper of the truck is reserved for heavy machinery and small castings in bulk, such as valves and the like, which can be loaded and unloaded without interfering with the piping—and vice versa.

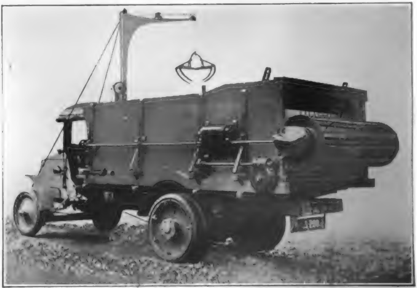

Fig. 363.—Combined Power Manure Spreader and Unloader.

Combined Power Manure Spreader and Unloader.—This device, illustrated at Fig. 363, is built on a six-ton Packard truck. The body holds six tons of horse stable manure as carried from cities. Its engine may load it from car to manure pile by using the grapple fork and crane. The body is 12 x 6½ x 3½ feet. The apron and beater are driven direct from the engine, independent of the wheels, so that it will deliver the manure either standing still or traveling as slowly or as rapidly as the truck can run. The beater can also be run at any speed, and delivers the manure in particles much smaller and finer than any horse-drawn spreader. The beater, 32 inches in diameter, can be removed easily, and an end gate substituted. Then the affair can be used for hauling anything, the apron remaining stationary while en route. Or by throwing in a gear, the apron can be made to travel and unload with the truck either moving or standing still—a most desirable scheme for handling garbage in feeding pigs in a hog lot. By detaching four bolts this Aue spreader may be lifted off the chassis and the regular body put in its place. Thus the one chassis can be used for both ordinary truck purposes and also for a manure spreader or automatic unloader. The originator expects to build a manure spreader attachable to the chassis of any size or make of truck or automobile.

Special Carrier for Lumber.—The Ross Carrier depicted at Fig. 364, A, is a special form of electric truck designed especially

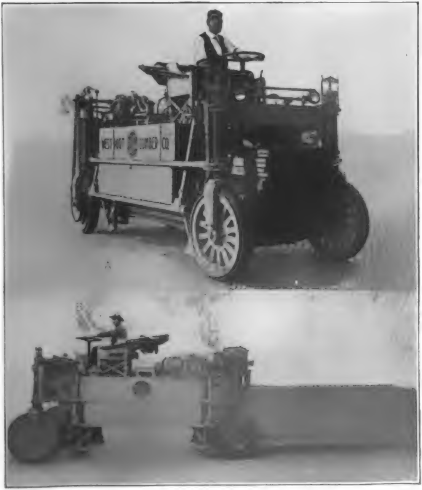

Fig. 364.—Special Motor Truck for Carrying Lumber.

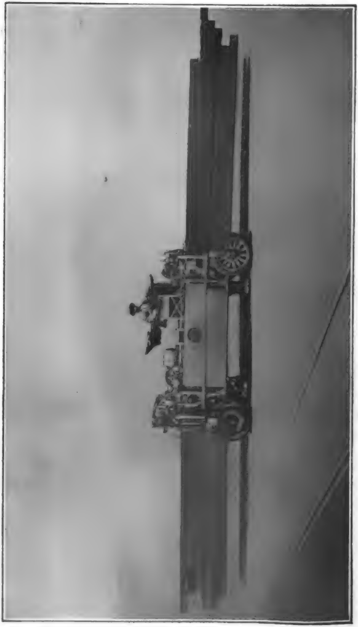

Fig. 365.—Side View of Electrically Propelled Ross Carrier for Lumber.

for handling structural material such as lumber, pipe and long structural shapes. The details, as furnished by the makers, show many interesting features of construction. It is equipped with an elevating device that is controlled by its operator without leaving his seat and is especially constructed to run over its load, as shown at Fig. 269, B, and to pick the load up by power furnished by the same motor that is used for driving the machine from the point of loading to the destination of the load. The motive power is storage batteries of alkaline nickel and steel construction and consists of 66 cells A-6 Edison storage batteries. These drive a motor of the usual electric vehicle type.

The frame of the carrier consists of two inverted U-shaped members connected by girders which also support the guides. These also carry the necessary mechanism to perform the functions of transporting its loads. The batteries are carried in boxes on both sides of the carrier.

This machine was designed primarily to solve a problem that has confronted large lumber mills, that of economically taking the lumber as it left the assorting chains and delivering it to the yard, dry-kilns, planers, or any other department. As an example of what this machine can accomplish, there is a record of handling 410,000 feet of lumber ranging from timbers to flooring in 10 hours. It would take at least ten horses and as many men to move this material by the horse and truck method.

The loading device consists of a cone clutch that is connected to a worm and worm gear and this through a gear reduction to two cable drums with a lead of wire cable that through a system of cable sheaves raises the hooks or feet that lifts and sustains the load. These hooks slide up and down in guides that are hinged in a manner that permits the entire member to swing outward far enough to clear anything the wheels may pass, and are arranged in a manner that permits them to engage a load that is not central with the carrier. However, when the load is lifted clear of the ground and swings to a central position, the guides automatically lock and remain in a rigid position until the load is set down and the locks released. The cone clutch used for the drive is operated by the same lever as the hoist and is connected in such a manner that either both clutches are out or either the driving or hoisting clutches are in; both cannot be engaged at once.

Driving power is first transmitted to a Timken worm-drive that is installed to serve the purpose of a jack shaft with the worm below. Through a series of universal joints the power is carried by means of sprockets and chains to the rear wheels. The wheels are carried in special fork fittings, and all are turned in their steering heads when turning the vehicle. The machine as shown in the photographs has the lifting hooks incorporated between the wheels and in such a position as to distribute the weight equally on all four wheels. This, of course, necessarily lengthened the wheel-base, and to offset any difficulty in handling the machine in close quarters all four wheels steer.

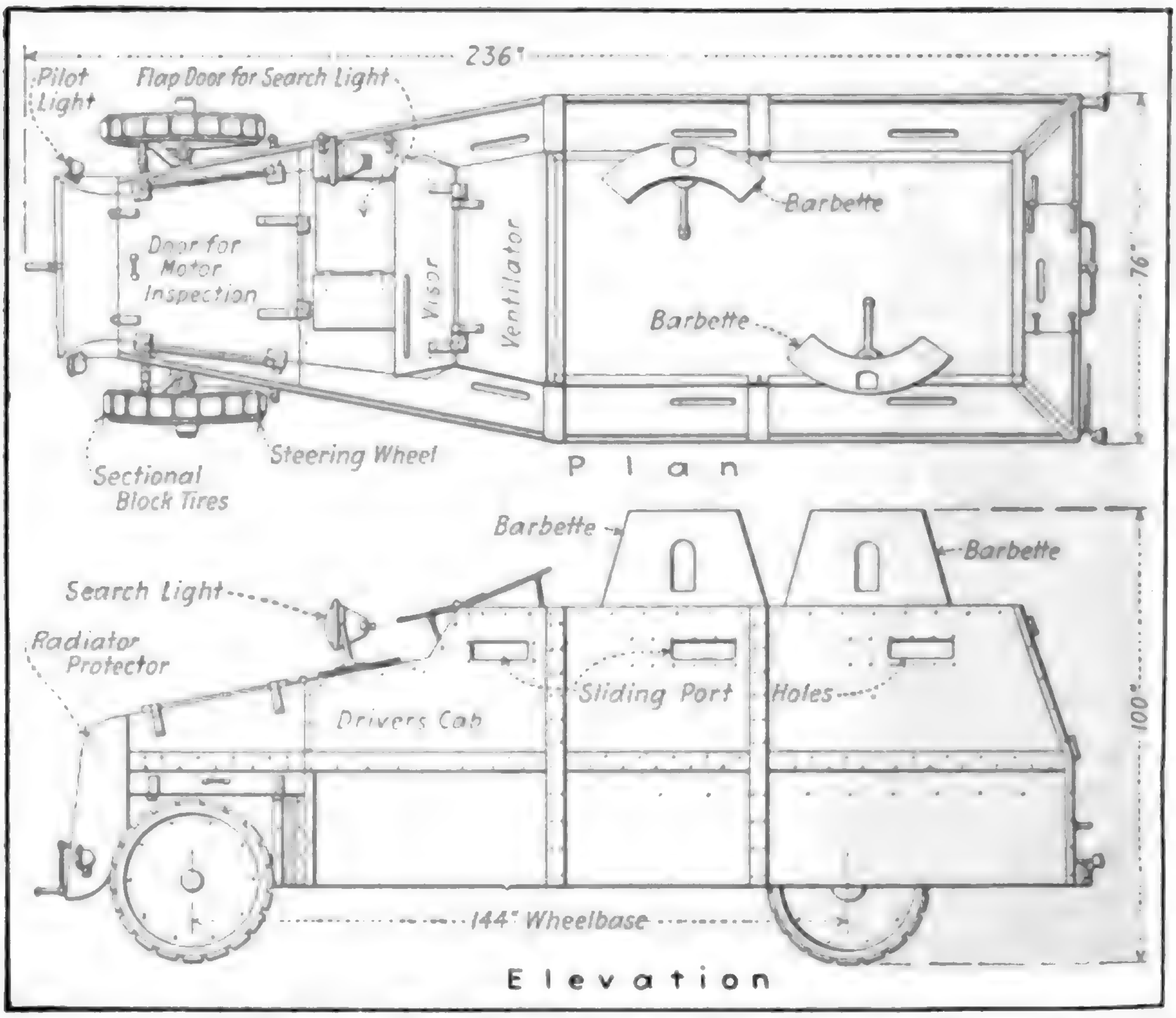
236"
Pilot Light
Flap Door for Search Light
Door for Motor Inspection
Visor
Ventilator
Barbette
Barbette
76"
Sectional Block Tires
Steering Wheel
Plan
Barbette
Barbette
Search Light
Radiator Protector
Drivers Cab
Sliding Port
Holes
100"
144" Wheelbase
Elevation

Fig. 366.—Plan and Side Elevation of Two-Ton Mack A. C. Armored Truck.

Armored Automobiles.—The European war has produced the development of special types of automobiles, designed for quick transit of rapid-fire guns and their crews. All portions of the cars are protected by alloy steel armor plates. The design shown at Fig. 366 is a patented construction in which a revolving turret capable of mounting two machine guns or rapid-fire guns of light caliber is used. The illustration gives the side elevation, plan and rear views of the truck, as well as a plan of the turret showing the various constructional features. Under modern conditions of warfare the cavalry forces that were formerly depended on for reconnoitering are useless for present-day work, as they are unable to withstand the effects of modern high-power artillery or rifles. On the other hand, armored motor cars can pass practically unharmed through a withering rain of rifle or machine gun bullets. The revolving turret permits the fire of the guns to be directed against the enemy irrespective of the direction in which the truck is traveling. All vulnerable machine parts are protected by substantial plates of armor steel. The radiator is protected by swinging doors of steel, which may be operated with a rod from the driver's seat and which can be closed when the automobile is subjected to gun fire. The sides of the body are brought down low enough to protect the engine base, transmission case and other parts that are exposed in the conventional chassis. Steel wheels and solid tires are used in preference to wooden wheels and pneumatic tires, which would be more subject to destruction by bullets. These war machines are usually geared for high speed and provided with high-powered motors.

The plans outlined at Fig. 366 show the conversion of a 2-ton Mack A. C. type chassis to an armored car of great offensive and defensive capacity. It weighs but 9,000 pounds complete with body and equipment, a remarkable figure when one considers the amount of armor plate carried.

The radiator is of specially large size to insure cooling under difficult operating conditions and to compensate for the somewhat restricted air circulation. The fuel tank is located below the floor, completely protected by the armor, and feeding by the Stewart vacuum system. For towing purposes, a special spring-cushioned drawbar is provided at the rear, anchored to the rear frame cross-member and extending in a ring back of the rear armor plate. As most of the armor slopes toward the top, the joining of the plates has been difficult. For this reason and also to prevent chipping the edges of the plates by bullets, butt straps are provided at all joints, thus making these doubly strong and preventing opening the seams.

To illustrate the painstaking care with which this armor has been constructed, the armor itself is cut and drilled at the steel mill and then the plates are straightened to conform exactly with the drawings. They are then heat-treated and cannot be drilled or machined again without re-annealing. All bolts and nuts used in the construction of the armor are of special steel, heat-treated and hardened, to prevent their being shot away. There are 600 of these bolts.

Barbettes are mounted on cast bronze frames and are arranged to pivot fore and aft and to swing from side to side. Their backward slope not only provides for bullet deflection, but permits of considerable elevation of the aim, useful in case of use in anti-aircraft work.

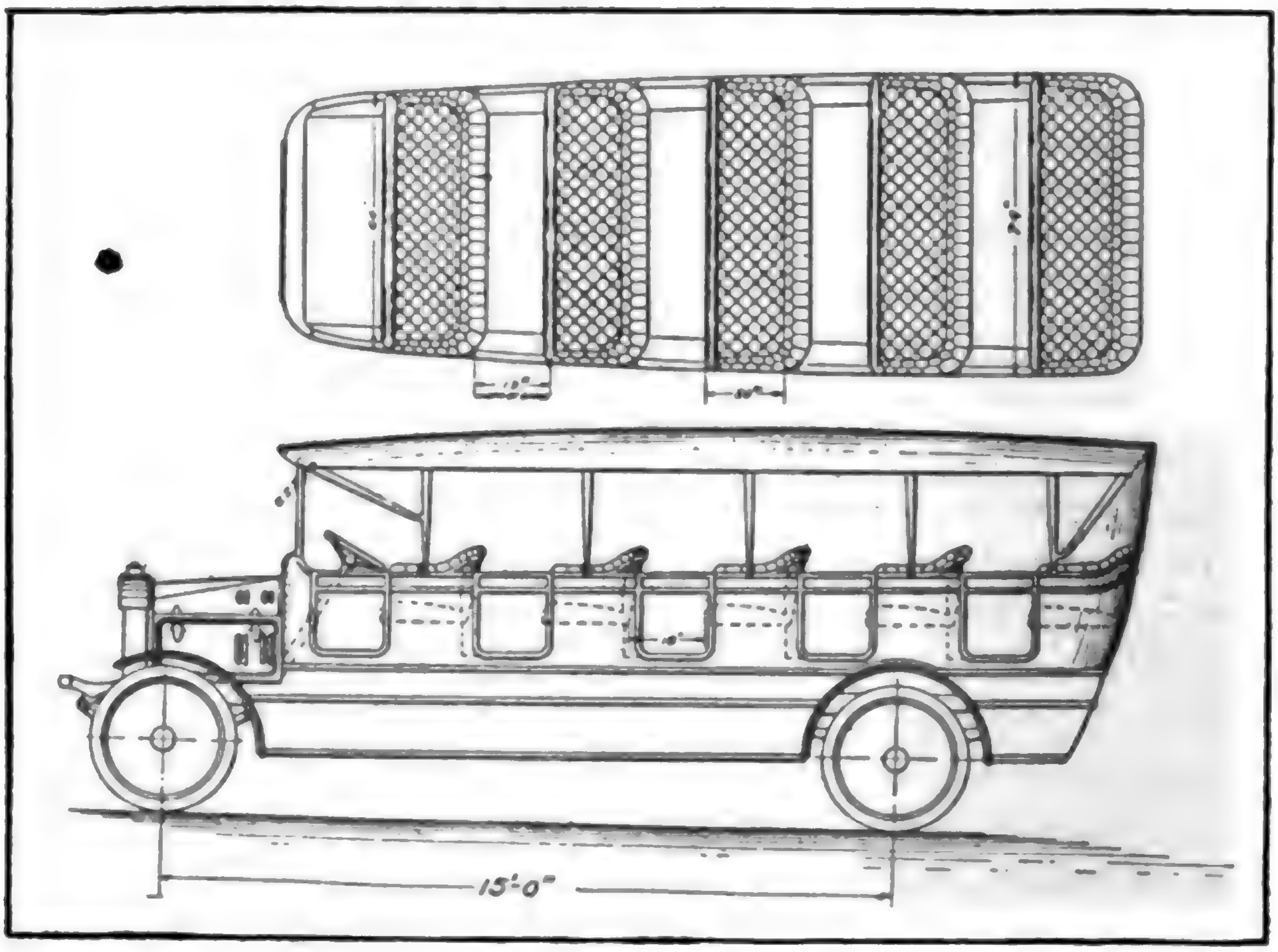

Fig. 367.—Main Dimensions of Typical Truck Fitted with Char-a-banc Body.

Detail weight of the different components follow:

Part	Lb.	Part	Lb.
Chassis	5,000	Extra Wt. radiator	15
Armor	2,400	Fuel tank, etc.	50
Frame for armor	600	Battery	67
Platform	200	Butt straps	250
Drawbar	40	Special bolts	60
Radiator guard	120	Barbettes	250
Total	9,052		

Mobile Repair Shops.—The wide use of trucks in the great war which raged in Europe had made it essential to develop special forms of repair trucks that were intended to accompany motor truck convoys and keep them in proper running order. These trucks may be of two types—the emergency wagon, as shown at Fig. 369, or the field repair shop, illustrated at Fig. 370.

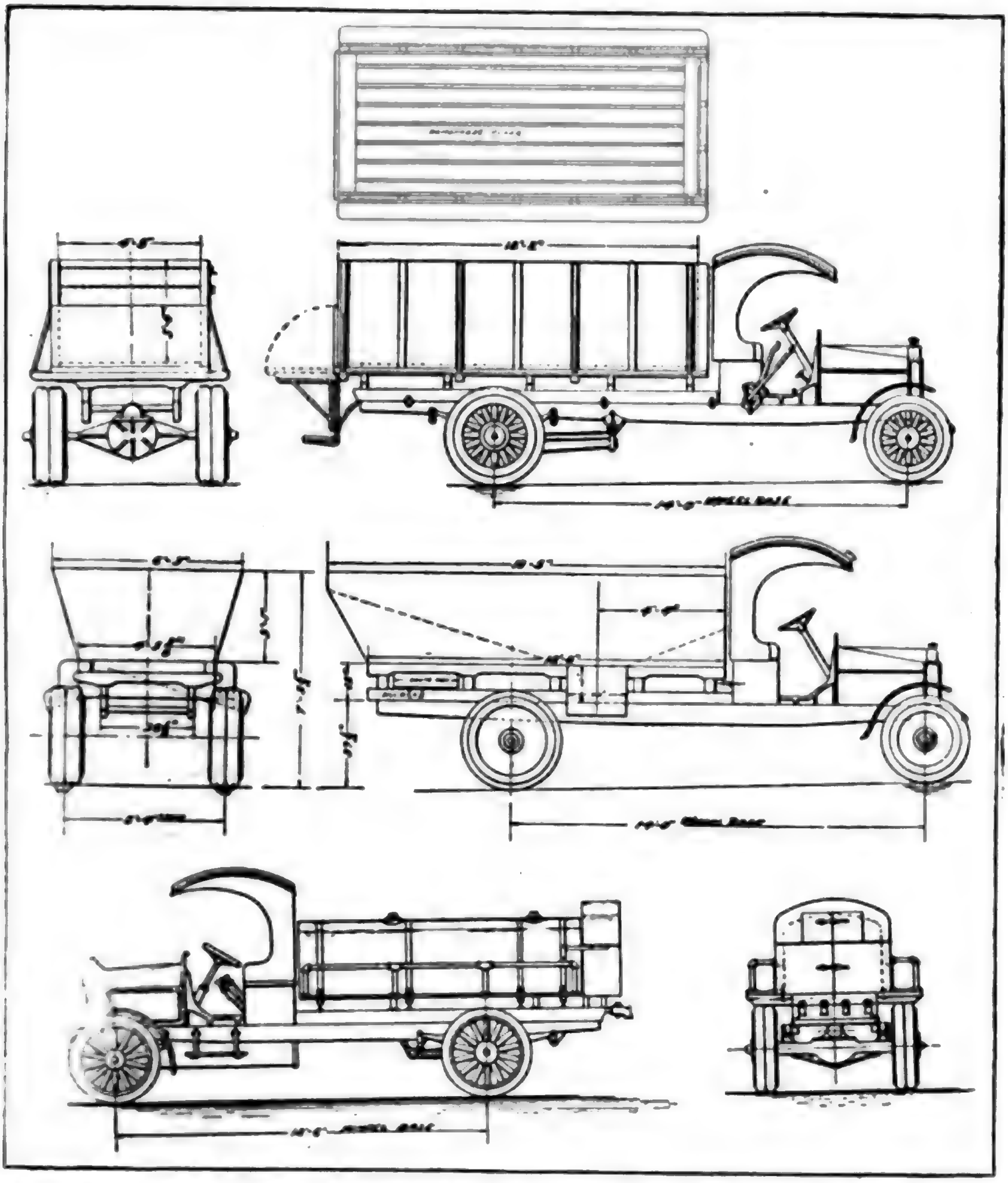

Fig. 368.—Typical Special Bodies Mounted on Modern 5-Ton Truck Chassis. Body at Top for Ice or Wood, that in Center is an Automatic Discharge Coal Body. Type Shown at Bottom is Tank Body for Oil Delivery.

The former is a Nash four-wheel drive and steer chassis equipped with a special steel body. It carries a work-bench, vise and full set of the small tools ordinarily used in making road repairs. An oxy-acetylene welding and cutting outfit and a small but very powerful derrick are carried for wrecking purposes.

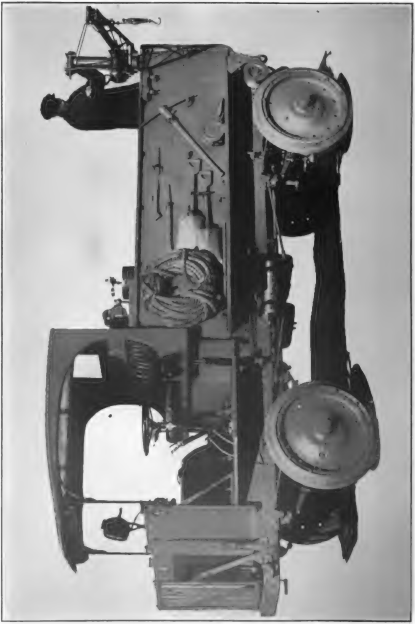

Fig. 369.—Emergency Repair Equipment for Army Use Mounted on Nash Four-Wheel Drive Chassis.

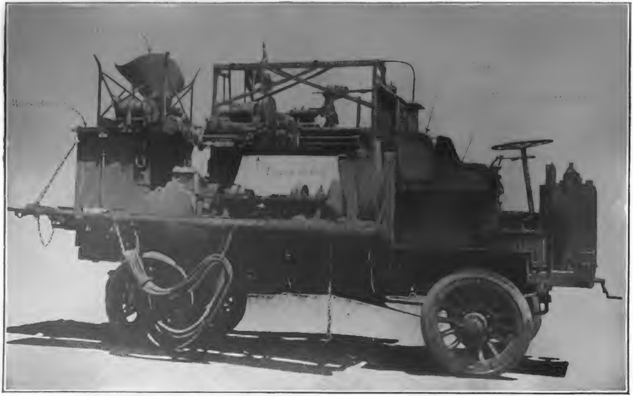

Fig. 370.—Complete Mobile Repair Shop Mounted on Four-Wheel Drive Truck Chassis.

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Coils of heavy rope, axes, shovels, picks, block and tackle and sledges are attached to the body sides to assist in extricating mired automobiles, repair roads, bridges, etc., and for general engineering construction or destruction work. Winch drums or "nigger heads" are carried at the rear of the frame, these being arranged so they can be driven by the engine power, and towing hooks are attached to both front and rear of frame.

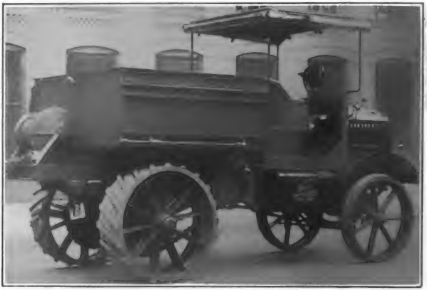

Fig. 371.—The Knox Military Type Four-Wheel Tractor Equipped with Side Dumping Body.

Other forms of repair trucks which have lathes, drill presses and other machine shop tools are also available, but these are generally used at the field base as a mobile repair shop rather than as tenders for convoys. A repair shop truck of this kind is shown at Fig. 370, the machinery being clearly shown packed ready for transit.

Utility of Tractors.—The tractor has a number of advantages for fire department work as well as in the commercial applications, and it has been thoroughly tested out in connection with all types of apparatus. Before considering the applications of the tractor and trailer combination, it will be well to enumerate some of its principal advantages, as follows:

First: Ease of attachment to any present horse-drawn type of

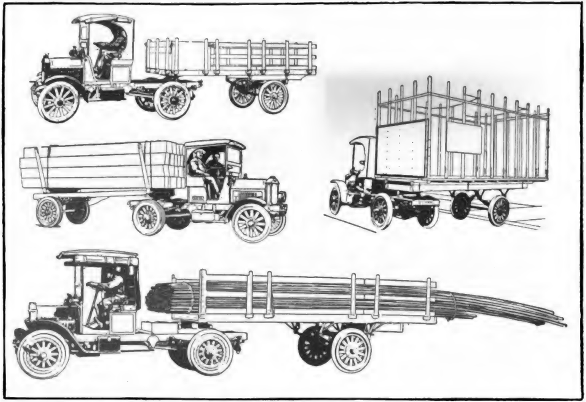

Fig. 372.—Features of the Semi-tractor Method of Hauling Heavy Loads and Various Types of Bodies that Can Be Used Advantageously.

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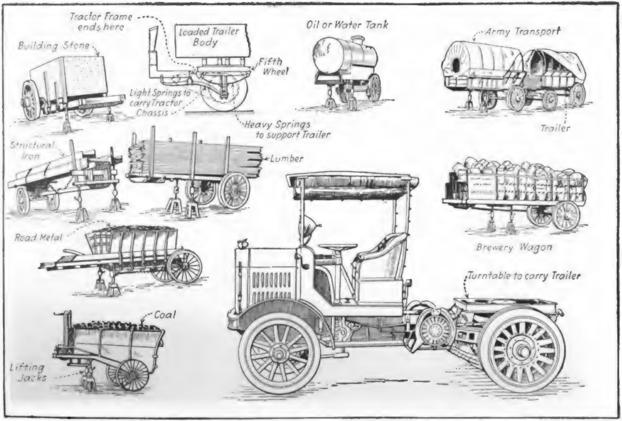

Tractor Frame ends here
Loaded Trailer Body
Building Stone
Fifth Wheel
Light Springs to carry Tractor Chassis
Heavy Springs to support Trailer
Oil or Water Tank
Army Transport
Trailer
Structural Iron
Lumber
Brewery Wagon
Road Metal
Turntable to carry Trailer
Coal
Lifting Jacks

Fig. 373.—Representative Road Tractor and Various Special Trailers that May Be Drawn by a Single Tractor Unit.

apparatus, thus saving the latter from the scrap heap or sale at sacrifice prices in order to effect motorization.

Second: Low first cost compared with a complete original integral motor outfit to do the same work.

Third: The factor of interchangeability is an important one. The tractor can be readily attached to any vehicle at the fifth wheel or turntable by means of an ordinary king-pin in a very few minutes' time. In small cities this is a distinct advantage, as one tractor can be made to serve several pieces of apparatus. Suppose, for instance, that after the fire engine had been taken to the scene of the fire and it was decided that a water tower would be needed to facilitate extinguishing the blaze, the front portion of the pumping engine could be jacked up without interfering with its operation and the tractor can go back to get the water-tower, which is needed so seldom in the average small town or city that it would not be necessary or profitable to provide a separate tractor for this piece of apparatus alone. Another advantage of interchangeability is that the use of the tractor does not alter the piece of apparatus appreciably, and if for any reason the tractor is incapacitated, horses may be used to draw the apparatus.

Fourth: The tractor can haul a considerably heavier load with the same amount of power than where the power plant forms an integral part of the piece of apparatus. The flexible rear springs of the tractor absorb the driving and braking reaction and permit the starting of heavy loads on grades or the positive control of the apparatus when descending hills without damage to the essential parts of either the apparatus or the tractor. As an example of the hauling power of the tractor, comparison may be made with the pack mule, which is able to carry one-third of its weight on its back, whereas the same mule will draw four times its weight without exerting itself any more than when carrying one-twelfth of that load. The tractor does not push or carry all its load, as is true of the conventional truck construction.

A large portion is carried by the trailer in the semi-tractor forms and all of the load when the tractor-train system of loaded trailers is followed. Various applications of the semi-tractor are shown at Fig. 372, and the wide variety of semi-tractors and loads they carry is depicted at Fig. 373.

Trailer Types.—There are three forms of trailers adapted for use with automobiles. The simplest is the two-wheeler form shown at Fig. 379, which can be adapted to any pleasure car chassis and used for light work. The wheels are arranged at the center of the body and will carry practically all the load if it is properly distributed. They use wood wheels and small section solid rubber tires. The specifications of the smaller model, which has a capacity of 800 pounds, are as follows: Body solid panel, 72 by 51 inches, 10 inches high, with 6-inch flareboard; springs, semi-elliptic underslung; axle, 1¼-inch square; bearings, ball; wheels, hickory with 30 by 1¾ solid clincher tires; painting, body red and wheels yellow with black striping; weight, crated, 375 pounds. The 1,200-pound model specifications: Stake body, 8 by 4 feet; side and end gates, 18 inches high, all removable; springs, semi-elliptic underslung; axle, truck type I-beam section, 2 by 1½ inches; bearings, anti-friction roller; wheels, hickory with 32 by 2 solid clincher tires; painting, black; weight, crated, 445 pounds. Automatic couplers are fitted, and these

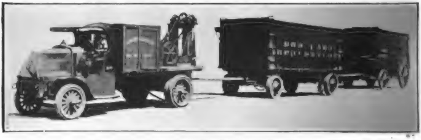


Fig. 374.—Mack Truck with Stake-Driving Equipment Hauling Two Circus Wagons as Trailers.

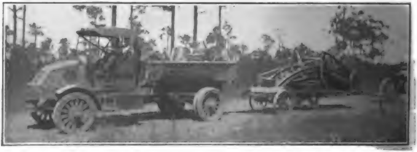


Fig. 375.—Kelly-Springfield Truck Hauling Road Scraper.

ig. 376.—Showing How Trailer Principle Can Be Advantageously Applied in Road Work. View at A Shows Kelly-Springfield Truck Hauling Road Roller. White Good Roads Truck at B and C, Used for Hauling Scraper and Road Metal.

an be attached and detached in a few seconds. Then there is the semi-trailer, which has but two wheels, as shown at Fig. 380. They cannot be used without specially built tractors to receive their front end. They may be made in infinite variety and are well adapted for heavy loads.

The Troy trailer, which is shown at Fig. 381, is a four-wheeler type having the wheels carried on steering knuckles so joined by levers that the wheels will track when rounding curves. This feature makes it possible to use several of these trailers, which are very substantial in construction, in the form of a road train behind any motor truck of sufficient capacity. As the trailers carry all the load, the truck is not called upon to carry any weight except that loaded into its body. In the semi-trailer type, part of the load must be carried by the tractor rear wheels, and we have what is in effect a six-wheeled automobile, articulated in the middle so the front and rear may assume different angles to facilitate steering.

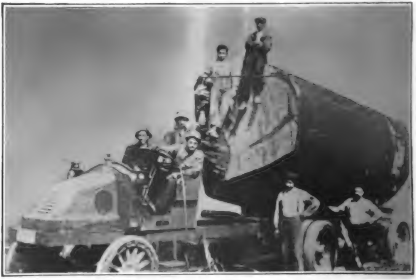


Fig. 377.—Kelly-Springfield Truck and Trailer Used in Lumbering Operations.

Other forms of tractors have been devised for hauling very heavy loads in which four driving wheels are employed to secure better traction. Some of the four-wheel drive tractors are of the gasoline-electric type and all four wheels combine directive and tractive functions, as the electric motor imparting power to the wheel is housed in its interior. The four wheels are mounted on steering knuckles, so they may be turned to any

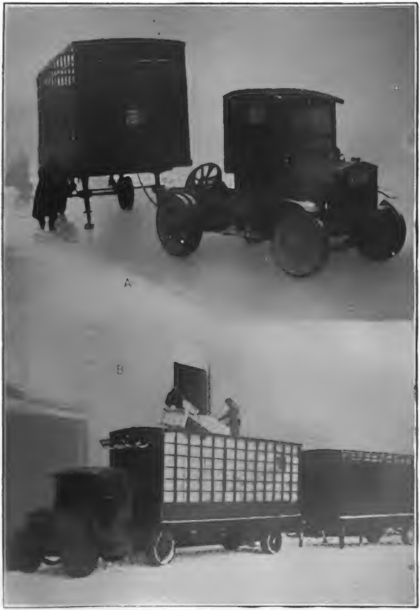


Fig. 378.—How Semi-Tractor Can Be Used in Hauling Large Loads of Empty Boxes. View at A Shows Method of Jacking Up the Trailer by Special Jacks so the Tractor Can Be Backed Under It.

desired angle for steering. A tractor of this form is shown at Fig. 382, and is of the Couple-Gear type. The power is generated by a four-cylinder gasoline motor which drives a dynamo, and the current from this dynamo is directed through a suitable controller to the motors in the four wheels. This system of drive is specially well adapted to moving very heavy loads, and the adaptability of the Couple-Gear tractor in hauling an extremely large and heavy coal wagon is clearly depicted. A full description of this method of drive will be found in the chapter on "Electric Trucks."

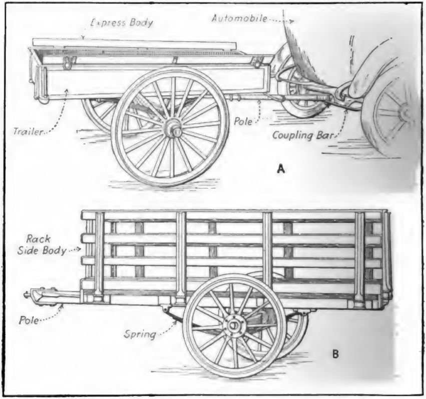
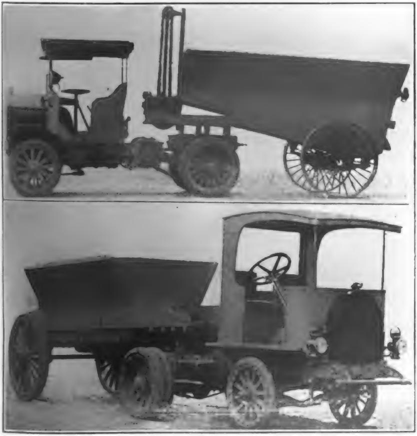


Fig. 379.—Light Trailers to Be Drawn by Pleasure Cars.

The Troy drop frame four-wheel trailer for heavy hauling and for use with a variety of dumping and special duty bodies is shown at Fig. 383. Its construction can be readily ascertained from the illustrations and the following specifications give its main features.

Capacity—Weight, 6,000 pounds; cubic yards, 4. Body Allowance—1,900 pounds. Tread—63½ inches. Wheel-base—115 inches. Ground Clearance—12 inches. Frame Length—175 inches. Height of Frame Under Load—At center, 18 inches; at ends, 32¾ inches. Height to Loading Edge of Body—60 inches. Frame Width — 43$\frac{3}{16}$ inches. Frame Section — 5 and 6-inch I-beam. Axles—Drop forged. Bearings—Double cage roller. Springs—2½ x 44-inch best grade spring steel. Wheels—Standard artillery, hickory spokes. Tires—36 x 5 solid rubber Pressed On Type. Loading Space—At center, 66¾ inches; at ends, 54⅛ inches. Overall Width—80 inches. Turning Radius—28 feet 3 inches, outside wheel. Weight, Chassis—3,530 pounds. Weight, Body—1,900 pounds. Total Weight—5,430 pounds.



ig. 380.—Two Semi-Trailer Outfits Adapted for Contractors' Use. The Knox Road Tractor is Shown at the Top and the Watson Tractor Hauling Bottom Dump Wagon at the Bottom.

A feature of the Troy trailers that makes them suitable for use in trains is the special drawhead and coupler shown at Fig. 384 which couples automatically, also a drawhead feature as

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shown at Fig. 385 that is as positive in action whether on uneven ground or in backing as it is on a straight-away pull. The drawbars are attached to steering knuckles on both axles, as shown at Fig. 386, so all wheels track when the train is running around a curve.

The operation of the drawhead under varying conditions is clearly shown at Fig. 385. The view at A shows the drawheads and coupler when wagons are moving forward. There is always an absolutely straight line of draft through the entire train. Note the hinge in center of link—the wagons can't possibly buckle or get out of line in making a turn. When the wagons are moving over rough or uneven ground there can be no climbing or drawheads or buckling of wagons. Any wagon in the

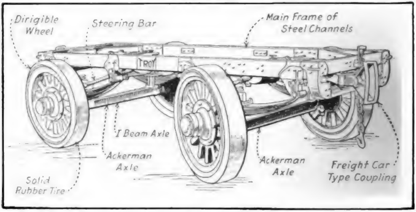

Dirigible Wheel
Steering Bar
Main Frame of Steel Channels
TROY
I Beam Axle
Ackerman Axle
Ackerman Axle
Freight Car Type Coupling
Solid Rubber Tire

Fig. 381.—The Troy Trailer has All Four Wheels Movable for Steering.

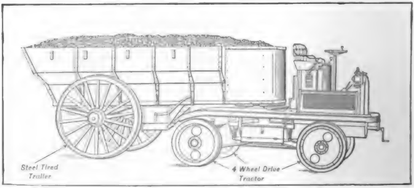

Steel Tired Trailer
4 Wheel Drive Tractor

Fig. 382.—The Couple Gear Four-Wheel Drive and Steer Tractor Attached to Large Coal Wagons.

train can drop into a rut 20 inches deep or climb an obstruction 20 inches high without any added strain on the wagons following, as shown at B. The position of the drawheads when the wagons are being backed in a straight line is depicted at C. No side bars are needed in backing either in a straight line or around a corner. No matter how uneven the surfaces, the train is always under perfect control.

Troy Slow Speed Trailers, as shown at Figs. 381 and 387, are built to haul in trains, behind Slow Speed Tractors. They are reversible—can be hitched to either end. This feature saves from a quarter to half an hour in turning the train. They may be used in trains of from three to six units; under favorable conditions more than six. The wheel-base is short and a close coupling between all units in the train makes it possible for Troy Wagons to follow perfectly in the track of the engine, go around sharp corners and pass through narrow roadways or alleys without obstruction. They can also be backed up to loading platforms and be directed or placed over or under bins or alongside cars or into quarries and sand pits. Built in four styles—Bottom Dump, Spreader Wagons, Platform and Extension Trucks. The Trucks are for hauling logs, lumber, pipe and long materials. The Hauling and Spreading Wagons are for

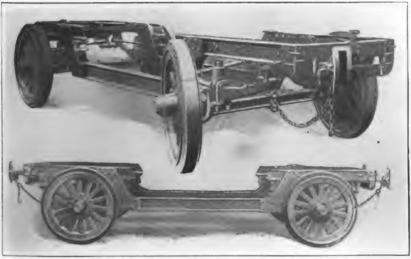


Fig. 383.—Troy Low Bed or Drop Frame Trailer.

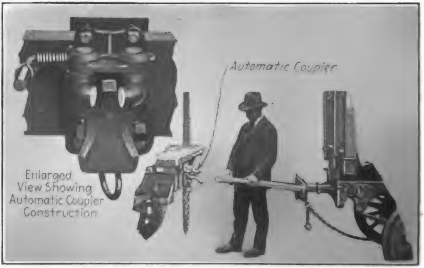

Automatic Coupler
Enlarged View Showing Automatic Coupler Construction

Fig. 384.—Automatic Coupler Used on Troy Trailers.

hauling loose material, such as clay, gravel, stone, sand, paving brick, coal, etc.

Drawbar Pull of Motor Trucks.—While the advent of the trailer several years ago was frowned upon by engineers of motor truck companies, special tractors have been sold intended to furnish the power for a road train of trailers, and these have worked out so well that they are finding ready sale. Many truck users have disregarded the cautions of the truck maker and have used four-wheel trailers, thus practically doubling the

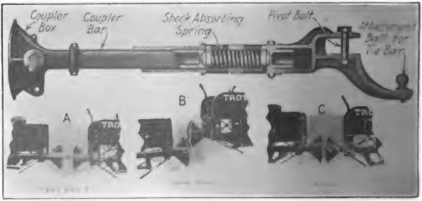

Coupler Box
Coupler Bar
Shock Absorbing Spring
Pivot Bolt
Attachment Ball for Tie Bar
A
TROY
B
TROY
C
TROY

Fig. 385.—Special Coupler Bar Used on Troy Trailers Makes for Positive Control When Used in Trains.

carrying ability of the truck and, as experience shows, with no appreciable injury to the truck mechanism unless the combination is unreasonably worked. So much interest now prevails in trailers that some of the truck makers have provided towing hooks and have strengthened their frame construction so trailers may be used without injuring the towing vehicle chassis. Of course, the special road tractors previously described are built especially for this work, and as some are provided with winches driven by the engine, they can pull their loads over poor roads and up grades where the tractor would not have sufficient traction to haul them in the conventional manner.

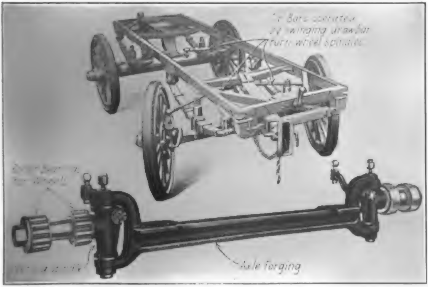


Fig. 386.—Typical Trailer Axle for Four-Wheel Steer Trailer and its Application on the Troy Product.

The amount a truck will pull when used as a tractor or in connection with trailers depends entirely upon the power available and the character of the highway over which it is operated. The Troy Wagon Works Company have made up a special chart, to permit determining the drawbar pull of any truck in order to estimate the load it will draw in the form of loaded trailers. The explanation of the chart which is shown at Fig. 388 is reproduced from the "Commercial Vehicle": "To get the answer you must know the bore and stroke and number of cylinders of the motor, the gear ratio and the rear wheel diameter. By using the tractive force chart you can obtain directly the tractive force of the truck. This is the total number of pounds push which the rear wheels of the truck can be expected to exert on the road surface. But how many tons will this force move? Select from the following table the value of road resistance, which applies in the case, then add 20 pounds for each per cent. of grade which the truck must climb, and the total tractive resistance in pounds per ton results.

TABLE OF ROAD RESISTANCE OF RUBBER TIRED TRUCKS AND TRAILERS

Type of Road	Road Resistance in Lbs. per Ton
Asphalt	20
Smooth brick	25 to 35
Poor brick, ordinary cobbles or macadam	35 to 60
Hard, dry clay road or hard gravel road	50
Soft macadam	75
Ordinary country clay road	100
Ordinary country sand road	150
Sand 3 inches deep	275 to 300

"Tractive force is the total number of pounds push available; tractive resistance is the number of pounds required to move 1 ton. By division the total number of tons which may be moved under the given circumstances is ascertained. If the weight of the truck plus the weight of a trailer plus the weight of the loads on both comes out less than the number of tons which the calculation shows can be handled, the use of a trailer is advisable. On good roads, with moderate grades, it will often be found that two, three or more trailers may be used with proportionate advantage. Example: A 5-ton truck has a $4\frac{15}{16}$ by $6\frac{1}{8}$-inch four-cylinder motor and 36-inch driving wheels. The total reduction on direct drive is 12 to 1 and on first gear is 43 to 1.

"From the chart it will be seen that the available tractive force for the high or direct drive gear reduction, 12 to 1, is 1,040 pounds, and for the low gear reduction, 43 to 1, is 3,730 pounds. In reading this chart it should be noted that two scales have been provided for the total gear reduction, one marked A and the other B, and that there are also two scales of tractive force marked A and B. When the gear ratio is between 4 and 16 the scale marked A should be used, and when the gear ratio is between 16 and 64 the scale B should be used. The truck, say, for example, is to be operated over a good crushed-stone road, the most of which is fairly level, but with one grade of 7 per cent. The road resistance, as we can see from the table, will be between 35 and 60 pounds per ton, and the total tractive force required on the 7 per cent. grade will be, using the higher value of road resistance, $7 \times 20 + 60 = 200$ pounds per ton. As 3,730 pounds are available on first gear, then $3{,}730 \div 200 = 18.65$ tons, which may be moved without overloading, the motor. If the

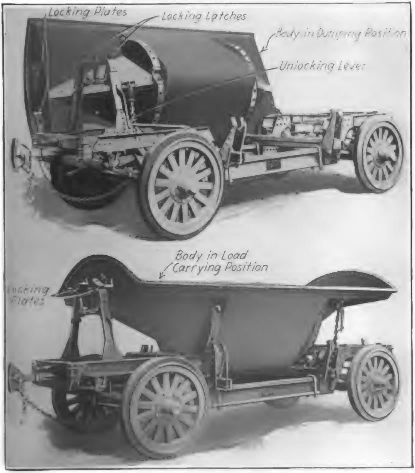

Locking Plates
Locking Latches
Body in Dumping Position
Unlocking Lever
Body in Load Carrying Position
Locking Plates

Fig. 387.—Troy Trailer with Special Dumping Body is Useful Equipment for General Contractors Employed in Excavating or Road Building.

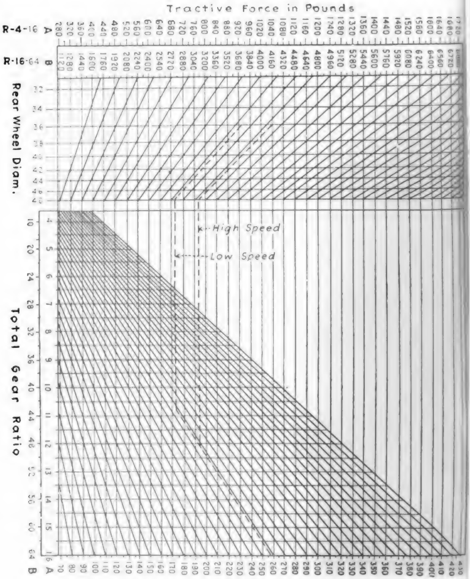


Fig. 388.—Chart to Determine Drawbar Pull of Motor Trucks

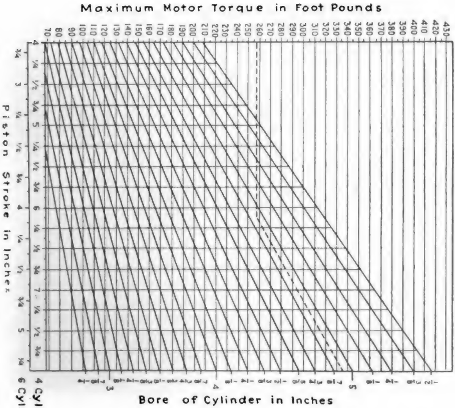


Fig. 388—Continued

weight of the five-ton truck is $4\frac{1}{2}$ tons and the weight of a five-ton trailer two tons, then using one trailer behind the truck with capacity loads on both, the weight of the train will come to $16\frac{1}{2}$ tons.

"As this comes out less than the calculated allowance, the use of one trailer under these circumstances is advisable.

"On level stretches of the road the tractive force required to tow the train would be

$$16\frac{1}{2} \times 60 = 990 \text{ pounds}$$

or 50 pounds less than the available force on direct drive of 1,040 pounds. It must be remembered that the chart values are not based on the performance of a new truck in perfect condition, but on the performance of a truck that has seen a year or so of hard service, but which has been kept in good condition. The chart values include all the margin of safety which is necessary under average conditions. Sometimes it will be found that the motor truck is geared too high to permit the use of trailers, even though conditions are such that a considerable economy could be effected by their use. In such cases a lower ratio should be installed in the truck. As a general thing, where the truck manufacturers offer optional ratios, lower than their standard ratios, then these lower ratios should be specified when ordering a new truck with which trailers are to be used, so that a greater tonnage may be handled on the trailers. This applies, of course, only in cases where total tonnage per day, rather than speed of delivery, is the chief object."

How to Use Chart.—This tractive force chart for motor trucks is based on the formula:

$$T = 0.55 \times D; \ F = \frac{7 \times R \times 12}{W}$$

when R is the total gear ratio, F is the tractive force in pounds, W is the driving wheel diameter in inches, T is the foot pounds of torque and D is the cubic inches of piston displacement.

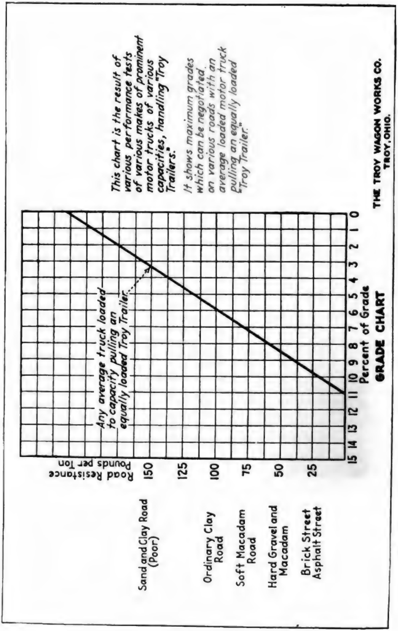
This chart gives the working value of the tractive force which may be expected from a truck used in hard commercial service. A new truck should develop a maximum tractive force 50 per cent greater than the value given in the chart. This chart is intended for chain, bevel, double-reduction or internal-gear-driven trucks, but not for worm drives.

Example—The dash line traces the solution of the following problem: To find the tractive force of a truck having a $4\frac{15}{16}$-inch bore, a $6\frac{1}{8}$-inch stroke and four cylinders; a 12 to 1 total gear-ratio in high and a 43 to 1 total reduction in low:

Solution—Starting with $4\frac{15}{16}$ on the vertical scale to the right of the chart, the line traces diagonally to the left, parallel with the nearest diagonal line to the intersection with the vertical line calibrated for $6\frac{1}{8}$ on the horizontal scale nearest the right. From this the line follows parallel with the nearest horizontal line to the left, reading 257 feet-pounds of torque on the vertical scale. Starting with the same 257 on the torque scale opposite, the line traces diagonally to the left, parallel with the diagonal, to the vertical line calibrated on the high-gear scale for 12, representing a reduction of 12 to 1. From here the nearest horizontal is followed to the left until it strikes the third section of the chart, where it continues diagonally to the left, parallel with the nearest diagonal line, to its intersection with the vertical line calibrated 36, for 36-inch rear wheels. From thence it follows the nearest horizontal line to the vertical scale at the extreme left. The answer is read on the A scale, to correspond with the gear-ratio scale used for high gear. The low-gear tractive force is found on the B scale in both instances.

Answer—The answer is read directly: 1,040 pounds for high gear and 3,730 pounds for low gear.

Grade Determination.—A writer in the "Automobile" explains the various methods of grade determination so clearly that any motorist, even if not familiar with geometry, can follow the discussion which refers to the diagram shown in Fig. 390. The matter of grade determination is an important one and many loose and incorrect statements are made that are based on incorrect information. The line A-F is approximately the steepest grade that an automobile is expected to ascend. Very few can do better and many will not reach it. An engineer would describe it as 60 in 100. It is also properly to be described as a 50 per cent grade, because the perpendicular drop from the point K is exactly half the length of the line A-K, and it can also properly be described as a grade which makes with the horizontal an angle of 30 degrees of arc. The 45-degree line from A to L is drawn as a matter of interest, because, from an engineer's standpoint, the horizontal distance and the rise being equal, it is properly described as 1 in 1 or 100 in 100 and it



This chart is the result of various performance tests of various makes of prominent motor trucks of various capacities, handling "Troy Trailers."

It shows maximum grades which can be negotiated on various roads with an average loaded motor truck pulling an equally loaded "Troy Trailer."

THE TROY WAGON WORKS CO.
TROY, OHIO.

Fig. 389.—Troy Trailer Capacity on Grades When Load Equals That on Truck.

is very improperly described as a 100 per cent grade, which it is not. It is, in fact, approximately a 71 per cent grade. It should be here said that the degrees are only approximately correct, and this is true also of all the figures relating to the grades of 5, 10 and 15 per cent, the errors being too slight to be noted. The absurdity of calling the 45-degree grade a 100 per cent grade is brought out by considering that it is perfectly possible to have steeper grades, as, for example, railroad embankments, so that one would proceed to 150 and 200 per cent grades, and at the point where the slope merges into the perpendicular, under this system of nomenclature, the grade becomes infinite.

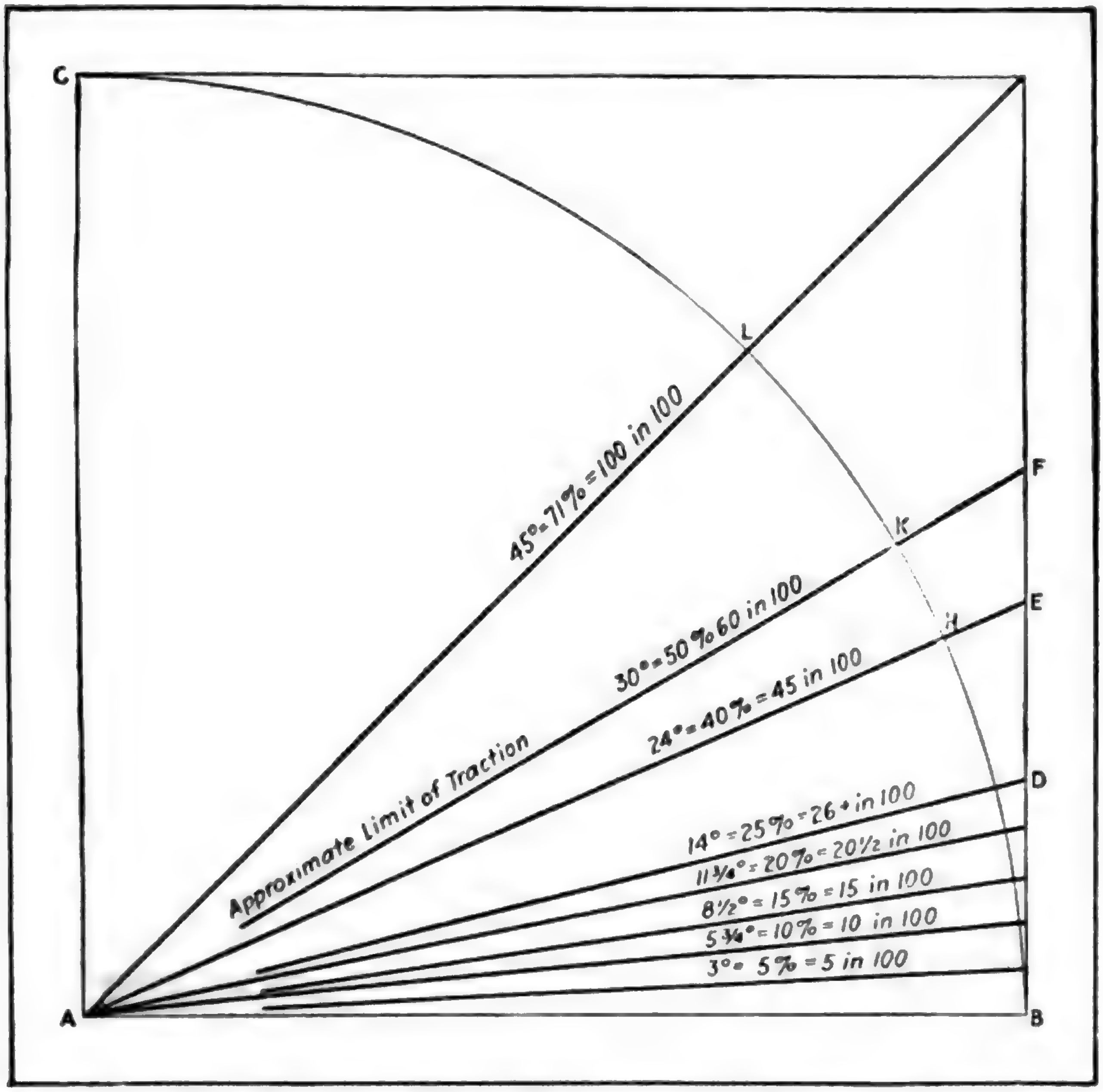

C
L
45°=71%=100 in 100
F
K
30°=50%60 in 100
E
H
24°=40%=45 in 100
Approximate Limit of Traction
D
14°=25%=26+in 100
11¾°=20%=20½ in 100
8½°=15%=15 in 100
5¾°=10%=10 in 100
3°= 5%=5 in 100
A
B

Fig. 390.—Diagram Showing Three Methods of Describing Grades so the Relation Between Angles, Per Cent. and Rise Per Hundred Feet Can Be Readily Understood.

On the other hand, there are very strong reasons for applying the per cent term to the grades that are designated by measuring along the slope and comparing that with the perpendicular. The horizontal is, of course, a zero grade. As the perpendicular is approached, the grade per cent increases to 90 per cent and above, but at the point where the perpendicular is reached the grade is 100 per cent. In other words, it is all grade and no horizontal advance. There is also the additional reason for using the per cent term, that where the weight of a vehicle is expressed in tons of 2,000 pounds, each rise of one per cent of grade requires an addition of 20 pounds of engine torque per ton to overcome it. This is to say, if a car is proceeding on the level and comes to a 10 per cent grade, its reserve torque must be at least 200 pounds per ton to carry it up the grade. If the grade increases to 15 per cent an additional 100 pounds is needed, and so on.

Fortunately, for the average owner the practical difference between 15 per cent and 15 in a hundred and any lesser grade is too slight to take into account, and on the main highways a grade exceeding 15 per cent is scarcely ever met with. It is said that the grade up Pike's Peak does not exceed 10 per cent at any point. Occasionally on back roads 20 per cent or 25 per cent grades may be encountered, but in those cases it is frequently the bad character of the road-bed that troubles the driver quite as much as the steepness, or degree of incline, of the road. The average automobile, if in good condition, should be able to surmount a 7 or 8 per cent grade on high gear. The effect of reduction to low gear and the enormous increase in reserve torque applicable to the surmounting of hills are illustrated when one multiplies 40 or 50 per cent of grade by the 20 pounds for each per cent of rise and finds that for the weight of his car in tons the engine must furnish on account of grade alone 800 to 1,000 pounds respectively of energy, a very considerable expenditure.

CHAPTER XI

ROAD TROUBLES AND TRUCK MAINTENANCE

Suggestions for Packard Truck Drivers—Cold Weather Procedure—Cranking in Cold Weather—Auxiliary Air Valve Adjustments—Stopping the Motor—Anti-freezing Mixture—Cooling, Lubrication and Driving Comfort of Mack A. C. Trucks in Hot Weather—How to Care for Mack Trucks Left in the Open in Freezing Weather—Cold Weather Hints—Care of Truck Springs—Practical Negatives—Engine Troubles—Noises and What They Indicate—Sounds Caused by Loose Bearings—Cause of Lost Power—Overheating—Muffler Explosions—Difficult Starting—Starting Impossible—Missing Fire—Chart for Engine Troubles—Engine Will Not Start—Engine Misfires, Idling—Engine Misfires, Pulling Hard at Low Speed—Engine Misfires at High Speed—Pierce Gasoline System and Carburetor—Riker Gasoline Supply—Riker Carburetor—Adjustments—Carburetor Troubles—Maxwell Truck Electrical Circuits—Charging Circuit—Ignition Circuit—Lighting Circuit—Horn Circuit—Reo Speed Wagon Electrical System—Riker Ignition System Maintenance—Riker Electric Equipment—Generator Battery Circuit—Light Circuits—Starting System Parts—Lighting and Starting System—Delco Faults—Two Unit System—Use of Test Lamp—Cleaning Lamps—Starting System Don'ts—Care of Storage Battery—Inspection and Care of Dynamo and Motor—Lamp Troubles and Their Causes—Washing and Cleaning Trucks.

Suggestions to Packard Truck Drivers.—Packard trucks are shipped from the factory properly adjusted and ready for service. It is very important that careful attention be given to periodical inspection and lubrication as outlined. Adjustments will, of course, be necessary from time to time to compensate for natural wear, and such adjustments should be made as soon as they are necessary, as otherwise excessive wear will be the result. Two views of a typical Packard truck chassis are given at Figs. 391 and 392.

The following information will show some of the symptoms resulting from misadjustments and also some of the minor troubles that are most apt to occur in a motor vehicle. The

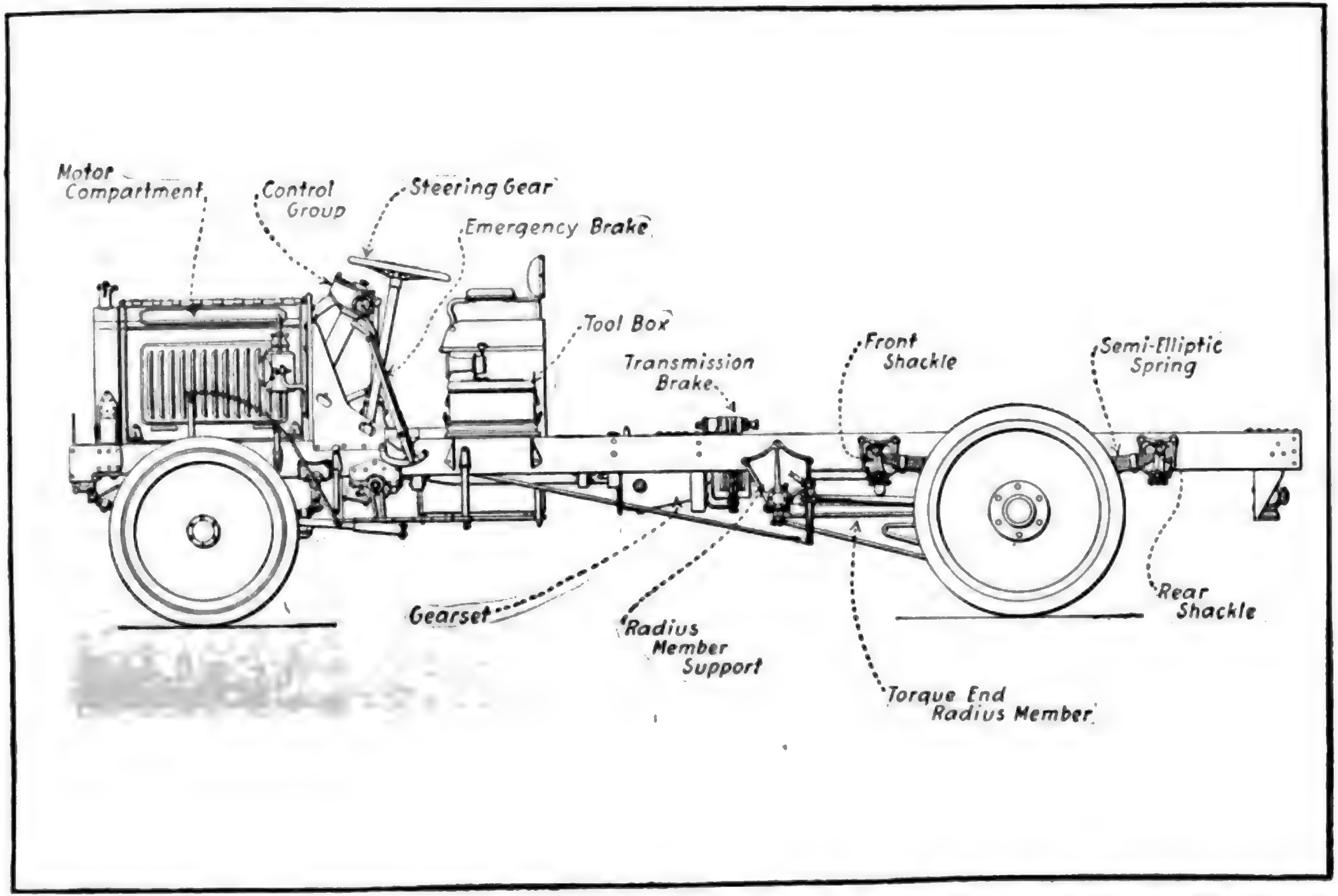

Motor Compartment
Control Group
Steering Gear
Emergency Brake
Tool Box
Transmission Brake
Front Shackle
Semi-Elliptic Spring
Gearset
Radius Member Support
Torque End Radius Member
Rear Shackle

Fig. 391.—Side View of Packard Truck Chassis. Note Use of Radius Rods and Torque Member to Take Driving, Braking and Propulsive Effort. Note Double Shackling of Semi-Elliptic Rear Spring.

possible causes of these disturbances are also given, with suggestions for remedying them, but in case it should prove impossible for the operator of the truck to overcome the difficulty by the aid of these suggestions, the matter should be taken up at once with an authorized Packard mechanic.

Motor Misses.—Carburetor improperly adjusted. Correct the setting of air and gas lever on control board.

Spark plugs improperly adjusted, porcelains broken or points carbonized. Each plug may be tested separately by making a metal contact between spark plug body and cylinder. If the short circuiting of any plug causes the motor to fire regularly on but three cylinders, that plug is very likely at fault. See further directions. Valves improperly adjusted or carbonized. Magneto dirty or improperly adjusted. Remove distributor plate and clean high tension distributor board. Clean interrupter housing cover and make sure that there is no carbon deposit between brass segments. See that all carbon brushes make good contact.

Ignition Circuits Defective.—Inspect for loose or broken connections, short circuits, etc.

Water in Carburetor.—Drain off through gasoline supply line strainer and carburetor, filter well drain outlet, also drain water from gasoline tank.

No air pressure.

Motor Cold.—Usually overcome after a moment's running.

Backfires Through Carburetor.—Gasoline mixture too lean. Set air and gas lever on control board near "Gas."

No Pressure in Gasoline Tank.—Gasoline tank empty.

Inlet Valves Not Seating Properly.

Water in Carburetor.—Remove through gasoline supply line strainer, carburetor filter, well drain outlet and gasoline tank draincock.

Motor Lacks Power

Cylinders carbonized.
Valves not seating properly.
Carburetor improperly adjusted.
  Correct the setting of the air and gas lever on control board.
Improper spark timing.
Insufficient lubrication.

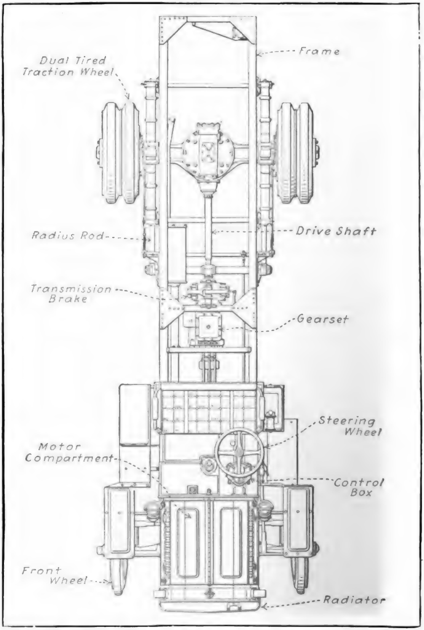

Dual Tired
Traction Wheel
Frame
Radius Rod
Drive Shaft
Transmission
Brake
Gearset
Steering
Wheel
Motor
Compartment
Control
Box
Front
Wheel
Radiator

Fig. 392.—Plan View of Typical Motor Truck Chassis, Showing Application of Top Worm Drive Axle and Gear Box Mounted Independently of Power Plant.

Motor overheated.
  Possible causes and remedies given below.
Governor connections sticky.
  Free up and lubricate.
Magneto weak.
  Consult a magneto expert.
Brakes dragging.
  See instructions for adjusting.

Motor Knocks

Too much spark advance.
Cylinders carbonized.
Motor badly overheated.
  Possible causes given below.
Loose bearings.
  Consult an authorized Packard mechanic.

Motor Overheats

Running on too rich a mixture.
Not enough spark advance.
Cylinders carbonized.
Fan belt improperly adjusted.
Radiator not full.
Anti-freeze in radiator in warm weather.
Insufficient lubrication.
Radiator or cylinder water jacket clogged with scale or rust.

Motor Stops or Fails to Start

No air pressure.
Gasoline supply shut off or tank empty.
Carburetor flooded or improperly adjusted.
  Correct setting of air and gas lever on control board.
Water in gasoline.
  Drain from gasoline supply line strainer, carburetor filter well and gasoline tank.
No spark at plugs.
  See possible causes under heading "Motor Misses."

Motor Won't Stop

Magneto interrupter brushes not making contact.
  Remove cover, clean, and if necessary, adjust.

Wire connections broken between coil and magneto interrupter posts.

No contact at coil switch.

Oil Pressure Low

Not enough oil in crankcase.

Refill to petcock level immediately.

Relief valve improperly adjusted.

Oil pump or relief valve screens dirty.

Remove and clean.

Relief valve not seating properly.

Determine and remove cause.

Pump not working or bearings badly worn.

Consult an authorized Packard mechanic.

Oil Pressure Too High

Oil cold.

Pressure will decrease after motor has run a few moments.

Relief valve improperly adjusted.

Gasoline Pressure Won't Hold Up

Leak in tank or air line.

Relief valve in pump improperly adjusted or seat dirty.

Clutch Slips

Pedal striking floor board.

Oil on plates.

Clean plates with gasoline.

Clutch facing worn out.

Replace.

Clutch Grabs

Shifter bearing sticky.

Lubricate thoroughly.

Gears Clash When Shifting

Clutch brake improperly adjusted.

Motor running too fast.

Reduce speed by closing throttle.

Clutch does not fully release.
    Improper adjustment of pedal.
Oil thick in transmission case.

Brakes Won't Hold

Shoes improperly adjusted.
Brake rods or pedal striking obstruction.
    Locate and make correct adjustments.
Oil on lining.
    Remove with gasoline.
Lining worn out.
    Replace.

Cold Weather Procedure with Packard Trucks.—During cold weather it is necessary to pay more particular attention to the setting of the carburetor air and gas lever on the control board, in order to produce a mixture which will be easily ignitable at the lower atmospheric temperatures. In extremely cold weather it is also desirable to conserve as much of the heat generated by the motor as possible by the use of radiator and hood covers.

The motor will run most efficiently during cold weather when the heat under the hood approaches the same temperature as attained during the summer running.

Cranking in Cold Weather.—Move the air and gas lever on the control board all the way over to "Gas" and crank the motor in the usual way, gradually moving the lever back a few notches toward "Air" after the motor is started. In extremely cold weather it may also be necessary to pull forward the button that is below the radiator at the right side. This shuts off the air in both primary and auxiliary intakes, thus causing a very rich mixture to be drawn into the cylinders. After the motor is started this button should be pushed back into position immediately. When the truck is equipped with an electric starter, use the button in the center of the control board. Without caution in warm weather or if the motor is warm, the mixture may be so rich if the button is pulled out that the charge will not ignite.

Auxiliary Air Valve Adjustments.—No hard and fast rule can be followed for the setting of the lever. It will be necessary to vary the setting to compensate for different atmospheric conditions and the temperature of the motor. Make a careful study of the manipulation of this lever, as experience will dictate better than anything else the proper running positions. Bear in mind, however, that even though a richer mixture is required, while the motor is cold than after it has become warm by running, it should be·given as much air as it will take. Too much air will cause a pop-back in the carburetor.

Always idle a cold motor after it has been started before running the truck. The heat thus generated will allow the motor to run on a leaner mixture and will insure the greatest possible gasoline efficiency, together with the most satisfactory lubrication. If the truck is operated with the carburetor adjusting lever at or near the "Choke" position, it will cause a waste of gasoline, an accumulation of carbon, and other unsatisfactory results.

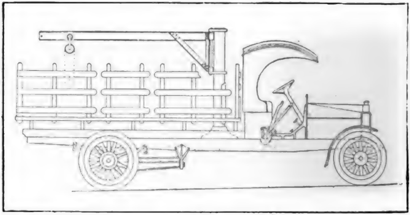


Fig. 392A.—Truck Equipped with Special Swinging Crane is Useful for Handling Heavy Loads and Also for Removing Truck Engines from Other Machines.

Stopping the Motor.—Before stopping the motor in cold weather, close the throttle to reduce the speed and then move the auxiliary air valve adjusting lever on the throttle board all the way over to "Gas" before turning ignition switch to "O." This produces a very rich mixture which will assist in starting the motor the next time.

Priming the Motor.—If the motor is too cold to start by any of the above methods, inject a small quantity of gasoline into each of the cylinders through the priming cocks. This provides an initial charge for starting.

Water in Oil.—At frequent intervals the crankcase should be drained to be sure no water is present. If this is not done the oil pump screen will become frozen and the pump inoperative, thus preventing oil circulation.

Draining Water System.—If the truck is not to be used during freezing weather, the water circulation system should be thoroughly drained.

Anti-Freezing Mixture. — During freezing weather fill the water circulation system with one of the following anti-freezing solutions:

For a temperature not lower than five degrees below zero:

Alcohol	15 per cent
Glycerine	15 per cent
Water	70 per cent

For a temperature not lower than 15 degrees below zero:

Alcohol	17 per cent
Glycerine	17 per cent
Water	66 per cent

Alcohol should be added occasionally to make up for evaporation. The glycerine does not evaporate. The above solution has been found to be entirely practical and is the best for several reasons. A simple solution of alcohol, while it is not injurious in any way, lowers the boiling point of the water. Consequently, on warm days, with the car standing and the motor running, the solution will tend to boil easily and evaporate. The boiling point of denatured alcohol is about 10 degrees higher than that of wood alcohol. The use of glycerine raises the boiling point of the solution. It is more expensive than alcohol and is slightly injurious to rubber. All things considered, a combination solution of alcohol and glycerine in water is the most satisfactory. It is best not to use a solution of calcium chloride or any alkaline solution, these being injurious to the metal parts.

If unable to obtain glycerine, a solution of thirty per cent. alcohol and seventy per cent. water can be used. The boiling point of this solution is higher than the glycerine-alcohol solution, and new alcohol must be added to make up for evaporation.

It is a good plan to occasionally test the solution by drawing a small quantity from the radiator and allowing it to stand outside. If it thickens, new alcohol should be added.

The capacities of the cooling systems are:

Model	Capacity	Model	Capacity
1-ton	7¼ gals.	4-ton	9¼ gals.
1½-ton	7¼ gals.	5-ton	9¾ gals.
2-ton	7½ gals.	6-ton	9¾ gals.
3-ton	7½ gals.		

If the radiator should become frozen on account of not containing the proper solution, do not run the motor until full circulation has been started. It is not possible to thaw a radiator by running the motor, because by doing so the current of air drawn by the fan may cause it to freeze up more solidly.

COOLING, LUBRICATION AND DRIVING COMFORT OF MACK AC TRUCKS IN HOT WEATHER

General Suggestions.—In hot weather and in hot climates. proper cooling, lubrication and comfort for the driver can only be attained by particular care of those portions of the chassis upon which these functions depend. The cooling system of the Mack AC truck differs in many ways from the conventional form. and to secure the superior results of which it is capable, it is necessary that the operator understand it first of all, and then that he give it the amount of care which the importance of its function warrants. He must not expect the truck to labor in low gear up long grades or through deep sand, perhaps with a trailer in tow and still keep cool if a carbon deposit is permitted to accumulate in the cylinders; if insufficient water is put in the radiator; if the oil level is low or the oil is of the wrong kind. A little forethought and a disposition to make sure of things rather than taking them for granted will be repaid by efficient work by the truck under the most trying conditions.

Carburetor.—At the beginning of a season of hot weather it is ordinarily necessary to change the carburetor adjustment, that for summer being usually a trifle leaner than that for winter. Overheating is sure to result if the carburetor is improperly adjusted. Great care should be taken that the adjustment, when made, is correct and then it should be left alone. It is impossible to maintain the proper carburetor adjustment if the driver tinkers with it every time the engine shows the least irregularity of running.

Timing.—Timing has an important bearing on cooling. The timing of the valves and magneto are plainly marked on the flywheel, and if anything like reasonable caution is exercised in assembling the engine after an overhaul, it will be properly timed.

In very hot climates where temperatures are excessive for any considerable part of the year, the engine may be made to run cooler, but at a slight sacrifice of power, by setting the camshaft one tooth ahead (early) on the timing gears, so that the exhaust valve opens earlier.

Ignition.—A weak spark, due to excessive lubrication of the magneto, dirty breaker or distributor or weak magnets, or attempting to run on the starting battery will have an effect similar to late spark timing and overheating will result.

Driving.—In negotiating difficult grades, many drivers permit the engine to labor in high to a point just short of stalling when if they dropped into intermediate they could make the grade at greater speed and less consumption of fuel. Furthermore, contrary to popular supposition, the engine will cool better if it is not obliged to labor excessively.

Exhaust.—Overheating can take place when there is no defect in the cooling system proper whatever, and it is only justice to the manufacturer and to oneself to eliminate all external causes first. Forty per cent. of the heat of combustion must escape through the exhaust. It follows, therefore, that if any part of the exhaust system is impeded, a part of this heat must be carried off by the cooling water, which will naturally raise the temperature above the safe limit.

Restriction in the exhaust system may exist in the form of carbon deposit in the exhaust manifold or (rarely) an undiscovered fin on the casting. Sometimes the exhaust pipe and muffler, too, become clogged with soot. Care should be observed that the gaskets between the muffler and exhaust pipe do not overhang and thereby restrict the opening. Mud should not be allowed to cake on the outside of the muffler or to clog the outlet.

Valve Tappets.—Overheating is almost sure to result if the valve tappets are improperly adjusted. These should have 0.005

to 0.006 inch clearance, which in an emergency may be gauged temporarily by an ordinary business card.

Water System.—The return water pipe from the radiator to the pump crosses the exhaust pipe at the rear of the engine. As sent out from the factory, these pipes are at least two inches from each other, but it sometimes happens that in making repairs on the engine they are assembled so that they touch. This naturally causes the water to heat up.

In some cases it is advisable to wrap the return water pipe with asbestos to prevent absorption of heat from the exhaust pipe.

In replacing the cylinder water covers, white lead is usually applied to the gaskets. If care is not taken in this operation, some of the white lead will get inside the cylinder jackets. This should not be allowed to occur, as the white lead will deposit on the side of the jacket and interfere with cooling or it will be carried along with the water, stopping up one of the radiator tubes or small cavities in the water jackets.

To secure proper results it is necessary that the radiator be filled as full as possible. This means that the level will be up to the base of the radiator filler. It is for this reason that the overflow pipe is carried up to this level. It should not be allowed to bend down below this level or it will drain the water below the proper level.

If the overflow pipe is allowed to become clogged or flattened by a blow or kink, steam will form in the top tank, under low pressure, which will not only lower the efficiency of the cooling system, but may blow the gaskets and hose connections in various parts of the cooling system or prevent circulation by forming a steam lock.

Hose Connections.—Only the best quality of rubber hose should be used for the water connections, such as is originally installed on the engine. In making replacements, the best plan is to purchase hose ready cut to the proper lengths from the International Motor Co. The inside tubing of cheap hose is apt to dissolve, the rubber particles being carried along with the water and clogging up the radiator tubes. Hose without rubber inner lining is apt to give trouble from the fabric becoming loose and flapping over the opening, shutting off the water.

In the spring it is well to go over the hose connections carefully, as some anti-freeze solutions have a deleterious effect upon rubber.

Use Only Clean Water.—In filling the radiator only clean water should be used. If necessary, the water should be strained through cloth where none but dirty water is obtainable. Above all, water containing oil should be avoided and water buckets in which oil has been kept should not be used.

Inspect Pump.—Upon occasions when it is necessary to replace the water pump packing it would be well to dis-assemble the pump and look for dirt or fins on the casing or rotor. The rotor especially should be bright and smooth.

Radiator.—Equally important as good water circulation and clean surfaces within the water system is good air circulation and clean radiating surfaces. The air screens at the sides of the radiator should not be obstructed. The circular screen at the nose of the hood should not be covered with the license plate. The screen on the inside of the dash should not be covered in hot weather, as half of the air is drawn through this.

The outsides of the radiator tubes should be kept clean. One cause of their accumulating dirt, in some instances, is excessive greasing of the blower. The grease cup should never be turned up so much that grease oozes from the bearings, for this will be thrown off by the blower and will lodge on the radiator tubes, collecting dirt. If the packing on the fan bearings is worn, grease will pass and be thrown. The radiator tubes may be cleaned by softening with water and then blowing out with compressed air. If the deposit is of grease a little gasoline may be needed to soften it.

It is important that the fan belt be kept to the proper tension and that it be held in line, so that it will run evenly.

Radiator Tubes.—The radiator core comprises 374 copper tubes, in two semi-circular units containing 187 each. Occasionally, when very hard water is used, these become clogged with mineral deposit. On the Pacific Coast, where the alkali water contains a great deal of deposit-forming mineral, a special core of large finned tubes is supplied, but elsewhere plain copper tubes are used. The use of anti-freeze solutions, natural corrosion and rust, leak-sealing compounds and the disintegration of hose connections, all contribute in time to filling up the radiator tubes, at which time it is necessary to cleanse them.

Local dealers in boiler compounds can usually recommend a scale compound, especially formulated for the type of water which is prevalent in the locality which will serve.

Another method which has given good results in past seasons is the following:

Introduce the following solutions into the cooling system:

A—An acid solution, consisting of 4 fluid ounces, sulphuric acid (H_2SO_4) in 10 gallons of water.

B—A caustic solution, consisting of 3 ounces of caustic soda and 3 ounces of carbonate of soda or soda ash in 10 gallons of water.

Great care must be exercised in handling the sulphuric acid as any splashing will cause severe burns wherever the flesh is touched. It will also destroy clothing and metals of all sorts.

Proceed as follows:

1st—Drain all old water from the truck by opening cock at base of pump and removing plugs at the base of each cylinder block, on left-hand side.

2nd—Close cock and replace plugs. Fill cooling system with acid solution, A. Run engine at moderate speed for 30 minutes. Drain.

3rd—Fill with clear water, run 5 minutes, drain off.

4th—Fill with caustic solution, B. Run engine at moderate speed for 30 minutes. Drain.

5th—Fill with clear water, run 20 minutes, drain off.

6th—Fill with clear water and operate as usual.

In case one or more of the tubes is found to be completely clogged with foreign matter, remove the radiator cap and top strainer and thrust a piece of stiff wire carefully through the tube. It will be found that every tube may be reached through the filler. Care must be exercised in this operation not to injure the tubes by applying too much pressure.

Lubrication.—Not all of the cooling of an engine is effected by the water, but the lubricating oil plays an important part, since this cools the bearings. Provision is made on the Mack engine for cooling the oil, both by water and by air. The reservoir at the side of the front cylinder block is separated from the cooling water by only a thin iron wall. As the oil in the crankcase reaches much higher temperatures than the water, this serves to carry away some of the surplus heat and in order to function properly it is necessary to keep the walls of the reservoir clean. The other cooling feature consists of fins cast on the aluminum oil sump at the bottom of the engine. These fins are exposed beneath the truck, but will become ineffective if permitted to become clogged with dirt and mud.

The oil serves to cool the engine in two ways, first by conducting the heat away, as it circulates, and second, by reducing the frictional heat generated, by lubrication. In order to perform the latter function properly, the oil must be clean, of the proper consistency and up to the proper level of the sump. Owing to the poor grade of fuel we are at present obliged to use in our engines, it has been found that the gasoline washes the lubricant from the cylinder walls and a mixture of gasoline and oil runs into the crankcase, where it destroys the lubricating properties of the oil in time. For this reason the oil in the crankcase should be drained and replaced with new oil every 1,500 miles. If this is not done the oil will be unable to properly lubricate the rubbing surfaces and heating will result.

The average working temperature of the oil in summer is higher than in winter, and so oil of the same body will be thinner. Sometimes it is advisable to use a grade heavier oil in summer. In excessively hot spells an especially heavy grade of oil may be required to maintain the oil at the proper consistency in operation. Where a heavier oil is used care should be taken not to work the engine too hard before it has warmed up.

Driver's Comfort.—A cool and comfortable driver is able to render more efficient service and is a more contented one than one who is overheated in summer. The Mack AC cab is positively ventilated and will stay cool in the hottest weather if it is permitted to cool itself as intended. Half the intake of air into the blower is through the grating on the inside of the dash. However, the doors of the cab should be kept closed if a cool cab is desired, since the hot air from the radiator is blown out through the side gratings of the radiator, and if the doors are left open it will blow back over the driver's legs, due to the slight forward angle of the door openings.

HOW TO CARE FOR MACK TRUCKS LEFT IN THE OPEN IN FREEZING WEATHER

General.—In freezing weather when trucks have been allowed to stand in the open for a long period of time, the following instructions and hints should be adhered to if serious trouble and inconvenience would be avoided. It is better business to take hours getting everything ready for the start and leave the truck intact and not in need of repairs than to spend only a few minutes trying to get started quickly and paying the repair bill afterward.

If truck has been left standing in snow or ice and the wheels have frozen to the ground, the wheels should be loosened with a crowbar or jack and the truck pushed by hand or toward a few feet to another spot before starting, but under no circumstances should the power of the engine be used to start the truck, until the ice joint has been broken. All movable connections, such as universal joints, brakes, brake connections and cams, clutch connections, brake shafts, clevises, etc., that may be frozen fast should be broken loose with kerosene and light oil. The power of the engine should not be applied for this purpose as serious clutch or bearing trouble or breakage may result.

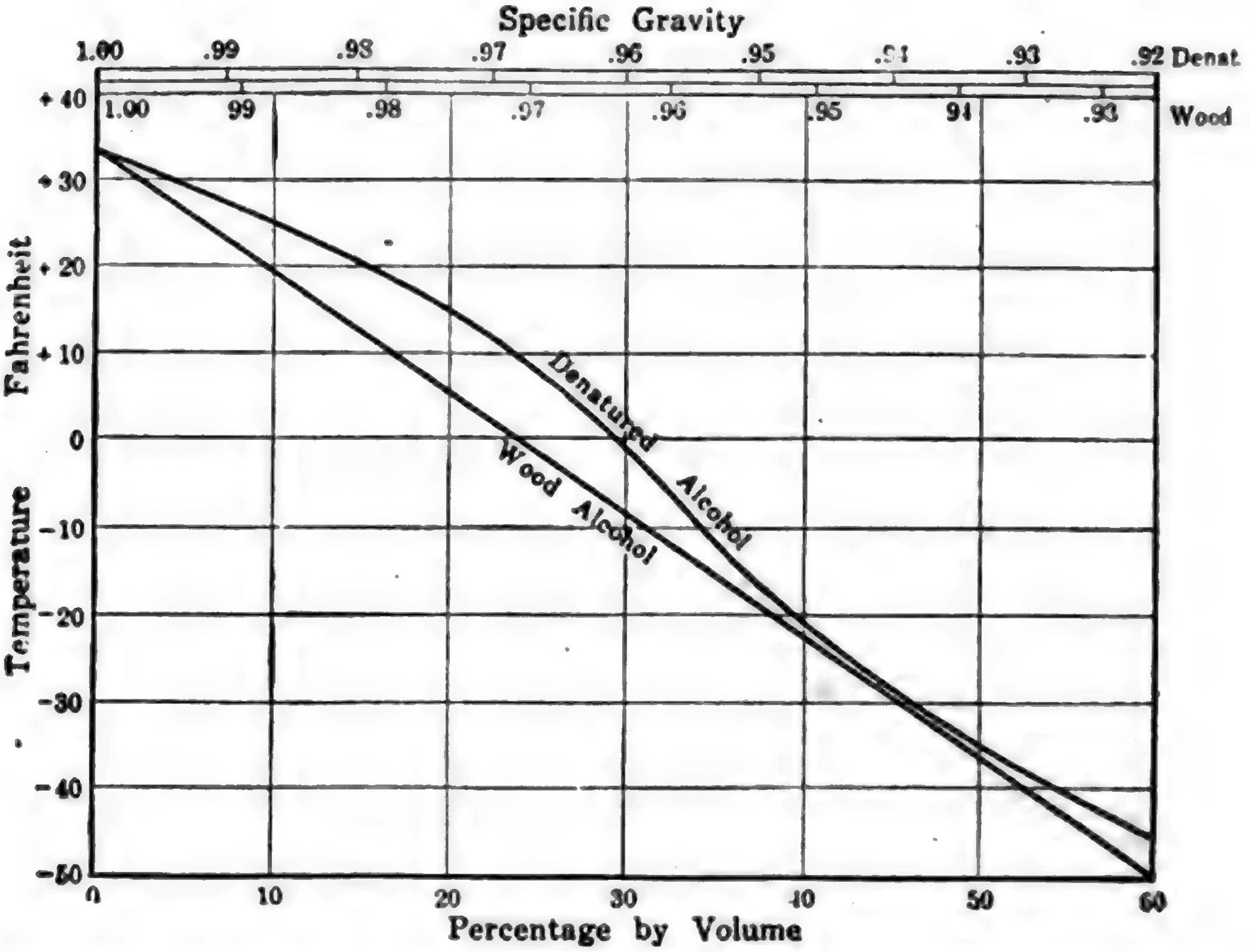


Fig. 393.—Freezing Points and Specific Gravity of Denatured Alcohol or Wood Alcohol Anti-Freezing Solutions.

What to Do with Engine.—A frozen engine should first be freed till it can be turned over by hand easily. Open the cylinder compression cocks and prime the engine with gasoline to remove moisture and to free the pistons, turn engine over by hand to clean out gasoline, then with an oil gun squirt light lubricating oil into the cylinders to replace that cut by the gasoline and to prevent scoring the cylinders. Remove the hand hole covers from the crankcase and with an oil gun squirt light lubricating oil into the main bearings, connecting rod bearings, wrist pin bearings and cam shaft bearings, as these parts will get little lubrication till the congealed oil in the crankcase is warmed.

Warming Up Motor.—This will prevent burned out bearings. Replace the covers and run engine slowly until it is heated up.

The engine will not heat up idling, cover front of radiator and retard spark and speed up gradually for about ten minutes. Do not race engine, especially during the first two minutes.

Lubrication.—Open the cylinder oil tank cover immediately after engine is started and see that the lubricating oil flows freely; if not, stop the engine before bearings are destroyed or cylinders scored and pour light lubricating oil into the engine through the cylinder oil tank. Make sure that the oil pump is working; if necessary remove it for inspection.

Fuel System.—If the engine is hard to start, pour warm water over the manifold to aid vaporization of the gasoline, make sure no water enters auxiliary air valve, pour warm water over the gasoline pipe to warm fuel. If water has frozen in the gasoline tank, gasoline pipe or carburetor, melt it by applying warm water, then drain off the water and remove and clean strainers in gasoline tank and carburetor. Don't crack the glass float chamber of the carburetor by pouring boiling water over it and don't flood carburetor with water.

All gasoline should be drained from the fuel system if truck is to be allowed to remain in the open for any great length of time to prevent the freezing of any water that may be contained in the fuel.

Ignition System.—Remove the spark plugs and see that each sparks properly as moisture may have frozen on the points, which must be cleaned off as it causes short-circuit. Inspect magneto terminals, breaker box and distributor and remove frozen moisture as this also causes short-circuit. Inspect all wires.

Inspect all wires to see that they are not short-circuited by freezing. Inspect the terminals of the auxiliary vibrating coil and clean if frozen moisture is present.

Inspect the battery and see that it is not short-circuited by ice formed across the terminals. If the engine starts hard, it may be due to the lowered efficiency of a cold battery; if so, remove it and place it in a warm place.

Cooling System.—Do not put hot water in the cooling system of a frozen truck, as the sudden change of temperature is likely to crack the cylinder jacket or cause leaks elsewhere in the system. Use warm water until the temperature of the cylinders has risen to a noticeable degree. When operating in freezing weather, put alcohol in water of cooling system.

Trucks should not be allowed to remain in the open in freezing weather, without first draining all the water out of the cooling system.

The diagram at Fig. 393 shows graphically the freezing points of various mixtures of alcohol and water and also gives the specific gravity for varying proportions.

	MODEL OF TRUCKS		
	1, 1½ or 2 Ton Mack (New Model "AB") 5-Ton Saurer 6½-Ton Saurer 1, 1½ or 2 Ton Mack (Old Model)	3, 4, 5, or 7½ Ton Mack (Old Style) 3½, 5½, 7½ or 10 Ton Hewitt	3½, 5½ or 7½ (New Model "AC") Mack
Lowest Temperature Usual in Your Vicinity	Pints of Wood Alcohol for Given Temperature	**Pints of Wood Alcohol for Given Temperature**	**Pints of Wood Alcohol for Given Temperature**
+25	2	3	4
+20	3	4	7
+10	6	8	13
0	9	12	19
—10	12	16	25
—20	14	19	31
—30	16	22	37
	Approx. Capacity of Cooling System 4½ gallons	Approx. Capacity of Cooling System 6 gallons	Approx. Capacity of Cooling System 10 gallons

Wood Alcohol Anti-Freezing Mixture.—To prevent freezing of cooling water in Mack-Saurer & Hewitt Trucks add the quantity of wood alcohol (in pints) as indicated in column under the heading "Model of Truck," opposite the temperature corresponding to the lowest usual temperature in your vicinity. The proportions recommended can be used in any truck that has the approximate capacity of the models given in the table on page 626.

Add more alcohol from time to time to make up for loss by evaporation. To guard against freezing, due to this loss by evaporation, one should test a sample of the mixture with a hydrometer every night and compare it with similar test when mixture was first made, adding wood alcohol to bring it up to the first reading.

Transmission.—Pour warm water over the transmission case to heat the gear grease so that it will soften and allow the gears to turn easily. If transmission oil is hard, soften by adding one gallon lubricating oil.

Put the gears successively in all speeds, jack up the rear wheels and turn over the engine by hand a few times before starting.

Rear Wheels.—Jack up one rear wheel at a time, put the gears in neutral and turn the wheels by hand a few times to free the bearings, the drive chains and the differential.

Clutch.—Move the clutch pedal forward a few times, first turning the grease cup and oiling the pins 7AC18 with kerosene and light oil. Throw out the clutch pedal and turn over the motor by hand, leaving the gears in speed to free the clutch lining from the flywheel.

Operation.—Do not drive close behind another truck when operating over bad roads. This is particularly important when operating truck trains or when operating in heavy traffic in storms or over snow or ice-covered roads in order to avoid collisions. Do not operate trucks light in snow or ice, use skid chains and have trucks loaded.

Cold Weather Hints

Adapted from "Fighting Snow," by Fifth Avenue Coach Company

Radiators.—Protect cooling water against freezing. (a) Add alcohol or some anti-freezing solution to cooling water; or (b) Heat garage; or (c) Draw off water every time truck is left standing with stalled engine for over half an hour outdoors.

Traction.—When snow falls, or roads are icy, equip truck with 1 shovel, 1 small pick, 1 box of sand, 12 skid chains for rear wheels.

It is possible to operate motor trucks successfully on snow and icy streets provided drivers use extreme care and follow these instructions.

Stopping.—When coming to a standstill, release brakes just before coming to a full stop, so that truck will roll the last few inches.

This will avoid formation of ice under the wheels which causes them to spin when starting.

Important Suggestions.—Start slowly. Do not attempt to force truck ahead faster than wheels will take hold. Spinning wheels, with or without chains, will not send truck ahead unless there is traction. If traction is lacking get out with shovel and sand and make it.

Do not, under any circumstances, grind skid chains between rubber tires and a hard road surface. Chains are intended for use in soft mud or snow. When the wheels cut through to hard road surface remove chains at once.

Feed small amounts of gas, let clutch in slowly, and you will find that wheels do not spin. Accelerate gradually. A slippery road surface does not offer the resistance of a dry road, and therefore the same rate of acceleration is not necessary or possible, as the excess acceleration produces spinning wheels.

Remember that the amount of power required to start or to stop a truck depends on the resistance of traction between the road and the driving wheels.

If road surface is slippery and driving wheels spin and skid, driving and braking effort will decrease accordingly, therefore—

"Do not drive down hill any faster than you can drive up."

Care of Springs.—In view of the instructions given in a preceding chapter there follows a list of things to be observed in the operation and care of the truck, if there is a desire to give the springs and other parts of the mechanism a fair chance to offer their longest life.

1. Evenly distribute load. Prevent shifting load.

2. Do not overload beyond rated capacity. The factor of safety allowed by the maker is for the owner's protection as well as the maker's.

3. A wheel out of round due to flat spots on a solid tire, imposes a severe and dangerous shock upon the springs. Keep the wheels round.

4. Give careful attention to all parts subject to friction. Keep them amply lubricated, as an excess of grease keeps the dirt out.

5. Take corners slowly, with or without load.

6. Back into a curbstone or platform gently. In driving the front wheels against the curb or any obstruction, the shock must be taken by the springs alone.

7. When the truck is loaded, drive gently over rough road or obstructions, remembering that the frame and springs must take the distortion.

8. Drive at moderate speeds at all times. Remember your solid tires have little resiliency.

9. If you have to tow the car, or have your truck towed, hitch the tow-rope to the frame—not to the axle.

10. If an accident occurs and a spring hanger or the frame near the hanger is bent, have it straightened at once. A spring distorted by a bent hanger is liable to break under load.

11. Keep spring clips tight at all times. If a center bolt should break due to loose clips replace it at once.

12. On a crowned road drive as nearly in the center as possible as driving to the right throws an extra load on the right-hand spring.

PRACTICAL NEGATIVES

Don't start on a trip without inspecting oil, gasoline and water supply.

Don't attempt to start with the ignition switch off.

Don't race the engine.

Don't start the truck with the brakes on.

Don't start the truck with a jerk. It racks the mechanism and destroys the tires.

Don't attempt to change gears with the clutch engaged.

Don't turn short curves at high speed.

Don't apply the brakes suddenly except in emergency cases.

Don't set the brakes when skidding.

Don't fail to keep the brakes operative.

Don't run on the street car tracks. The rails will cut the tires.

Don't overload the truck.

Don't let mud dry on the truck.

Don't fail to keep the truck clean. This means inside and out.

Don't fail to observe the rules of the road.

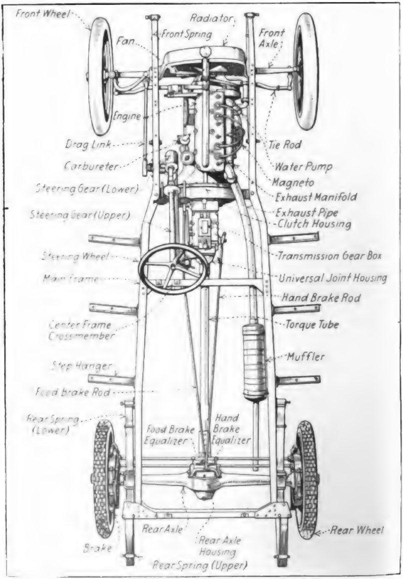

Front Wheel
Radiator
Front Spring
Fan
Front Axle
Engine
Drag Link
Tie Rod
Carbureter
Water Pump
Steering Gear (Lower)
Magneto
Exhaust Manifold
Steering Gear (Upper)
Exhaust Pipe
Clutch Housing
Steering Wheel
Transmission Gear Box
Main Frame
Universal Joint Housing
Hand Brake Rod
Center Frame Crossmember
Torque Tube
Muffler
Step Hanger
Foot Brake Rod
Rear Spring (Lower)
Foot Brake Equalizer
Hand Brake Equalizer
Rear Axle
Rear Axle Housing
Rear Wheel
Brake
Rear Spring (Upper)

Fig. 394.—Plan View of Dodge Light Truck Chassis Showing Parts Needing Periodical Inspection. This is a Special Army Model with Magneto Ignition.

Googl

Engine Troubles

Knocks.—Engine will knock for the following reasons:

1. Loose main bearings.
2. Loose connecting rod bearings.
3. Loose wristpins.
4. Piston slap.
5. Spark too early.
6. Pre-ignition.
7. Spark too far advanced for load.
8. Excessive carbon.
9. Engine overheated.
10. Lack of oil.
11. Engine support bolts loose.
12. Camshaft bearing worn.
13. End play to camshaft.
14. Timing gear back lash.
15. Loose flywheel.

DIFFERENT SOUNDS WHICH ARE CAUSED BY LOOSE BEARINGS IN MOTOR

A loose main bearing will pound with a dull thud when pulling under a heavy load.

A connecting rod pound is a lighter and sharper thump than a main bearing.

A wristpin knock is a sharp light tap and is noticeable when the motor is running idle—more pronounced when the spark is retarded on low throttle.

A piston slap is a light metallic knock, more pronounced when the spark is advanced, picking up speed from about four miles per hour, and can be eliminated by shortening the spark plug.

LOSS OF POWER

The following will cause the truck to lose power:

1. Dragging brakes.
2. Incorrectly timed distributor.
3. Lack of compression.
4. Engine overheated.

5. Wheels out of line.
6. Lack of lubrication.
7. Carbonized cylinders.
8. Carburetor not adjusted correctly.
9. Faulty distributor point adjusted.

OVERHEATING

Engine will overheat for the following reasons:

1. Lack of water.
2. Fan belt broken or slipping.
3. Water pump not working.
4. Oil pump not working.
5. Rusty or scaly radiator.
6. Clogged water jacket.
7. Defective water hose.
8. Valves out of time.
9. Distributor timed late.
10. Faulty carburetor adjustments.
11. Driving with retarded spark.
12. Excessive carbon.

MUFFLER EXPLOSIONS

Explosions occur in the muffler for the following reasons:

1. Mixture too lean.
2. Exhaust valve sticking.
3. Exhaust valve riding.
4. Dirty or sooting muffler.
5. Distributor improperly wired to plugs.
6. Accumulated unburned gases in muffler.

The engine compression may be poor for the following reasons:

1. Valves leak compression.
2. Valve plugs priming cocks or spark plugs leak compression.
3. Piston rings or cylinder walls worn or scored.
4. Valve warped.
5. Valve not seating.
6. Valve stem bent.

The exhaust may be smoky for the following reasons:

1. Oil feed too great.
2. Oil too thin.
3. Pistons, piston rings or cylinders worn.
4. Mixture too rich—black smoke.

STARTING DIFFICULT

There may be difficulty starting the engine for the following reasons:

1. Battery weak.
2. Spark plug electrodes too far apart.
3. Carburetor set for too lean mixture.
4. Poor compression.
5. Distributor breaker points sticking.
6. Distributor breaker points dirty.
7. Low test gasoline.
8. Air leak in intake manifold.
9. Ignition wire connection off.

STARTING IMPOSSIBLE

It may be impossible to start engine for the following reasons:

1. Switch not on.
2. Empty gasoline tank.
3. Gasoline line clogged.
4. Water in carburetor.
5. Carburetor float sticking.
6. Poor compression.
7. Fouled spark plugs.
8. Weak battery.
9. Distributor wire off.
10. Poor mixture.
11. Air leak in intake manifold.
12. Overpriming.

MISSING FIRE

The engine may miss fire for the following reasons:

1. Broken spark plug insulator.
2. Spark plug gap too wide.

3. Poor carburetor adjustment.
4. Air leak through valves or through intake manifold.
5. Circuit breaker points pitted, burned, short-circuited or out of adjustment.
6. Valves riding on tappet.
7. Valves' clearance too great.
8. Leaky valves.
9. Valves sticking.
10. Poor compression.
11. Excessive oil in combustion chamber.
12. Break in high tension circuit.
13. Poor distributor connections.
14. Broken, loose or disconnected high tension wires.
15. Weak battery or defective coil.
16. Water in fuel.
17. Restricted fuel flow, not filling float chamber.
18. Foul spark plugs.

DAILY MAINTENANCE ROUTINE-ENGINE

1. Tighten all wire terminals.
2. Tighten any loose nuts.
3. Note tension of fan belt.
4. Inspect oil pump, for performing its function.
5. Fill radiator.

The following tabulations show a method of systematic procedure to locate engine troubles that were prepared for instructing the drivers in the U. S. Army Ordnance Department and which is reprinted from government publications because of the complete manner in which the various derangements are outlined. The first thing to do is to see if there is compression or not, then if there is a spark at the plugs. This determines the next step, as outlined in the tabulations.

ENGINE WILL NOT START

- NO COMPRESSION
  - VALVES
    - Improperly timed or adjusted.
    - Timing gear key sheared.
    - Timing gear teeth stripped.
  - CYLINDERS
    - Overheated or overprimed.
    - Scored—cracked.
    - No lubrication.
    - Warped.
  - PISTON RINGS
    - Broken or stuck.
    - Worn or poorly fitted.
    - Weak or warped.
- GOOD COMPRESSION
  - VALVES
    - Improperly adjusted.
    - Improperly timed.
  - CARBURETOR
    - No gasoline—shut off.
    - Poor gasoline (heat).
    - Air valve stuck open.
    - Nozzle plugged.
    - One drop of water in nozzle.
    - Choker closed.
    - Improperly adjusted.
    - Manifold leaking.
    - Throttle or lever loose on shaft or stem.
    - Throttle disconnected.
- SPARK AT PLUG
  - Gap too wide.
  - No gap.
  - Oil soaked.
  - Wires on wrong plug.
  - Insulation broken or cracked.
  - Dirt on outside of porcelain.
  - Water on outside of porcelain.
- NO SPARK AT PLUGS
  - *Switch "off"*
  - *Cable insulation broken*
  - *Switch circuit grounded.*
  - *Magneto*
    - Breaker points improperly adjusted.
    - Breaker points badly pitted, worn or oiled.
    - Breaker arm sticks.
    - Safety gap closed.
    - Collector ring dirty or oiled (grounded).
    - Condenser punctured.
    - Coil circuit punctured or broken.
    - Brush worn, sticking, or broken.
    - Piece of brush grounding current.
    - Oil soaked.
    - Distributor disc punctured.
    - Water soaked (condensation).
    - Coupling key sheared.
    - Distributer disc dirty.
    - Distributer improperly timed.
    - Magnets demagnetized.

ENGINE MISFIRES, IDLING

- **CARBURETION**
  - Mixture too rich.
  - Low speed spring loose.
  - Float too low.
  - Manifold leak.
  - Poor gasoline.
- **IGNITION**
  - Spark plug gap too close.
  - Magneto timed early or late.
  - Magneto breaker gap too close.
- **POOR COMPRESSION**
  - **VALVES**
    - Improperly timed.
    - Valve stuck.
    - Tappets stuck.
    - Tappets adjusted too tightly.
    - Camshaft broken (rare).
    - Cam, roller or pin broken (rare).
    - Exhaust valve or seat cracked.
    - Warped from heat.
    - Stem bent or carbonized.
    - Pitted valve seat.
    - Stem and guide worn.
  - **CYLINDERS**
    - Overheated.
    - Scored.
    - Warped.
    - Not lubricated.
    - Overprimed.
    - Cracked (combustion chamber).
    - Cap gasket leaking.
    - Pet cock leaking.
  - **PISTONS**
    - Warped (binding rings).
    - Too small—twisting rings.
    - Cracked.
    - Broken.
    - Blowhole.
  - **RINGS**
    - Broken or weak.
    - Worn or improperly fitted.
    - Stuck or warped.
  - **SPARK PLUG**
    - Gasket leaking.
    - Porcelain chipped.

ENGINE MISFIRES PULLING HARD AT LOW SPEED

- **VALVES**
  - Head or stem—bent, warped.
  - Stems and guides worn.
  - Tappet adjusted too tightly.
  - Tappet adjusted too loosely.
  - Cam or roller broken.
  - Tappet roller pin broken.
  - Improperly timed.
  - Pitted.
  - Cracked.
  - Broken.

- POOR COMPRESSION
  - CYLINDERS
    - Scored.
    - Cracked.
    - Worn.
    - Not lubricated.
    - Overheated.
  - PISTON
    - Cracked.
    - Broken.
    - Warped.
  - RINGS
    - Broken.
    - Worn.
    - Stuck.
    - Weak.
    - Warped.
    - Poorly fitted.
  - GASKETS JOINTS
    - Spark plug packing.
    - Pet cock open—loose.
    - Spark plug gasket.
- CARBURETION
  - CARBURETOR
    - Mixture too rich or lean.
    - Insufficient hot air.
    - Gasoline supply restricted.
  - MANIFOLD
    - Gasket broken.
    - Flange nuts loose.
    - Cracked (test with gasoline).
- IGNITION
  - SPARK AT PLUGS
    - Timed late.
    - Plug gap too wide.
    - Plug oily.
    - Plug porcelain cracked or broken.
    - Plug center electrode warps.
  - NO SPARK AT PLUG:
    - Cable insulation punctured.
    - Cable strand frayed (grounding).
    - MAGNETO
      - Distributor improperly timed.
      - Distributor disc punctured.
      - Distributor dirty.
      - Distributor cover loose.
      - Condenser punctured.
      - Points pitted, worn, oiled.

ENGINE MISFIRES AT HIGH SPEED

- CARBURETOR
  - Backfire.
  - High speed nozzle plugged.
  - Gasoline supply to carburetor restricted.
  - Insufficient hot air.
  - High speed air valve spring too stiff.
  - Valve fluttering.
  - Mixture too rich or too thin.

ENGINE MISFIRES AT LOW SPEED

IGNITION	Spark plug gap too close.
	Spark plug center electrode warps.
	Magneto timed late.
	Magneto breaker bar sticks.
	Breaker point loose.
	Spark retarded.
	Magneto breaker cam worn.
VALVES	Valves stick.
	Tappets stick.
	Springs weak.
	Springs broken.
	Improperly timed.
	Cam or roller chipped.
	Cam or roller broken.

Pierce Gasoline System.—The gasoline system consists of (1) gasoline tank, (2) gasoline supply line, including shut off valve, pipe line, sediment trap and draincock, (3) priming pump, (4) carburetor. Gasoline flows by gravity from the tank through the valve "1" and through the pipes "2" and "4" to the carburetor.

Gasoline Tank.—The gasoline tank is located under the seat, as shown at Fig. 395, and has a capacity of 25 gallons. It has a large filler hole on the top which permits of inspecting, cleaning and repairing the inside of the tank and also facilitates the removal of articles which sometimes find their way into the tank.

In filling the tank, care should be taken to see that the gasoline is strained, in order to remove any foreign substance contained in it. It is of extreme importance that the gasoline is absolutely clean, free from water, dirt, etc. As a precaution against fire, always stop engine while filling tank.

Gasoline Supply Line.—The flow of gasoline from the tank to the carburetor, Fig. 395, is controlled by means of a lever at the right-hand side of driver's seat, just above the frame channel. When this lever is in a vertical position, the gasoline is shut off, when turned to the left, it is open, and when turned to the right, a reserve supply of about five gallons becomes available.

Between the shut off valve and carburetor is a sediment trap or collecting chamber and a draincock for draining off sediment and water which may be in the gasoline. This draincock should be opened for a few seconds about once a week in order to drain off foreign matter that may have accumulated.

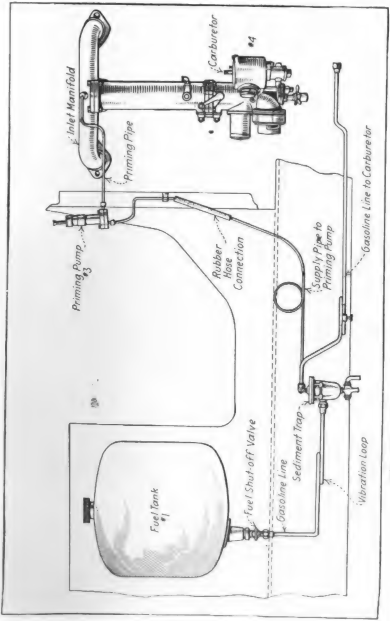

Inlet Manifold
Carburetor
#4
Priming Pipe
Priming Pump #3
Rubber Hose Connection
Supply Pipe to Priming Pump
Gasoline Line to Carburetor
Fuel Tank #1
Fuel Shut-off Valve
Gasoline Line
Sediment Trap
Vibration Loop

Fig. 395.—Complete Fuel System of Pierce-Arrow Truck.

The gasoline passes from the tank through the gasoline pipe and sediment trap. Before it can enter the carburetor, it must go through a fine gauze strainer in the carburetor. The screw cap or strainer plug "9," Fig. 396, B, to which this strainer is fastened, should be withdrawn about twice a month to allow the water and dirt to be drained off, first turning shut-off cock to "off" or vertical position. It may be necessary at times to clean gasoline pipe. This can be done by disconnecting the unions and blowing out all air pressure.

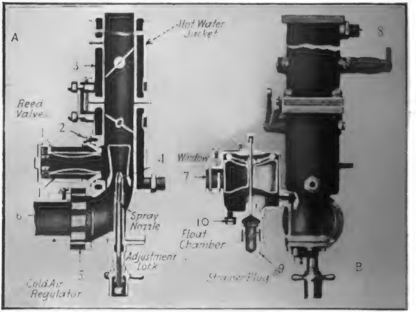

A
Hot Water Jacket
3
Reed Valves
2
1
1
4
6
Spray Nozzle
Adjustment Lock
5
Cold Air Regulator
8
Window
7
10
Float Chamber
9
Strainer Plug
B

Fig. 396.—Pierce-Arrow Truck Carburetor.

Primer.—The priming pump is located on the dash and is shown at Fig. 397. This is connected with the gasoline tank, also with the intake pipe of the engine, and is used to supply a surplus of gasoline for starting the engine when the engine is cold. The priming pump is operated by drawing the plunger to the top, at which time the cock should be closed, i.e., lever should be in a vertical position. It must be open or in a horizontal position before pushing the plunger down and must be closed at once.

Carburetor.—The carburetor is clearly shown in the two views at Fig. 396 and performs a most important function, namely, regulates the amount of fuel delivered to the engine. When this is out of adjustment a great waste of power and gasoline will result from too rich a mixture, or with gasoline supply below a certain point engine will refuse to run properly. The supply of gasoline is controlled by a needle valve "4" at the bottom of the carburetor and is set at the factory. UNDER NO CIRCUMSTANCES SHOULD THIS ADJUSTMENT BE ALTERED BY ANYONE OTHER THAN AN EXPERT MECHANIC WHO IS THOROUGHLY INFORMED.

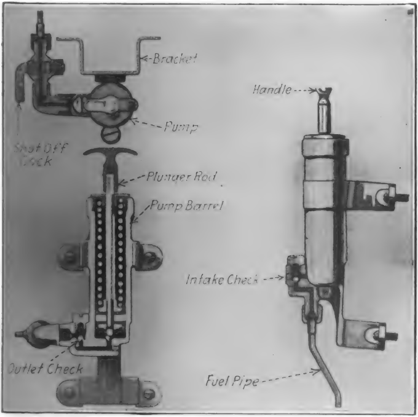

Bracket
Handle
Pump
Shut Off Cock
Plunger Rod
Pump Barrel
Intake Check
Outlet Check
Fuel Pipe

Fig. 397.—Hand Pressure Pump of Pierce-Arrow Truck Fuel System.

The carburetor is of the automatic float feed type with adjustable jet area. The auxiliary air is admitted through carefully calibrated reed valves "1." The main air is drawn in through pipe "6," Fig. 396, A, attached by means of a hood to muffler pipe. In the side of the float chamber a small glass window, "7," is located for indicating the level of the fuel. See Fig. 396, B.

A cold air regulator, "5," Fig. 396, A, is located at the rear of the carburetor. This permits of regulating the temperature of the air going into the carburetor. In warm weather the pointer on the regulator should be set over to read "open" and in cold weather the pointer should be set to read "closed." In the same way intermediate points can be maintained.

There is also a hot water jacket, "3," around the mixing chamber. The pipe from the carburetor to outlet water pipe has a cock in it. In hot weather this may be closed partly or entirely, but must be open in cold weather. In northern sections of the country it may be necessary to cover lower half of radiator to insure good working engine temperature. The lower grades of gasoline can be used if enough heat is available to vaporize it. A change in temperature or altitude may demand readjustment of the needle valve, which, as stated above, should only be made by an expert mechanic who is thoroughly informed.

Care and Maintenance.—The gauze screen on the cold air regulator, as well as the screens covering the reed valves, should be cleaned with gasoline at least twice every month. If these screens are not kept clean at all times the air supply is partially choked off, thereby causing the engine to use an excess of gasoline. When removing and cleaning the screen over reed valves it is well to see if the reeds are clean. When dirty the entire arrangement should be taken off and washed in gasoline. This can be done by removing screws "2," Fig. 396, A. Care should be taken not to disarrange the reeds "1" or strain them in any way when washing. It is essential for slow, smooth running and good operation that all flange connections between carburetor and engine be kept airtight.

The flooding of the carburetor, causing a leakage of gasoline, is usually due to dirt under the needle in the float chamber. As previously mentioned, the small strainer plug, "9," Fig. 396, B, located under the float chamber, should be taken out occasionally (about twice a month) and cleaned, in order to remove any foreign matter and allow free passage of the gasoline into the float chamber. The float chamber can be drained by removing cap screw "10," also shown in this view.

Riker Gasoline Supply.—The gasoline tank is located under the driver's seat. It is connected to the carburetor by a soft brass pipe, through which the gasoline flows by gravity. The flow of gasoline may be stopped by a valve on the under side of the tank. The filling hole is provided with a gauze strainer for preventing dirt or other impurities from getting into the tank. Warning: Do not use any fuel which is acid in its reaction with litmus (that is, turns blue litmus red).

Carburetor.—The carburetor is the Ball & Ball "Riker Truck Model." It is of the two stage type with a non-adjustable air valve, which opens only at high engine speed and is clearly shown in illustrations, Figs. 398 and 399.

The first stage is of adequate capacity for city traffic and ordinary running, and gives the highest motor efficiency for this type of work. The second stage is arranged to be used in conjunction with the first stage to obtain maximum power.

The hand throttle on the steering wheel and the foot accelerator are connected to the throttle lever (Section B) which operates both the first stage butterfly valve (Section C) and the second stage valve. The action of the second stage opening is very rapid and is accomplished by simply entirely depressing the accelerator or fully advancing the hand throttle. The operator can tell when the limit of the first stage is reached, as the High Speed Throttle Lever Spring (Section B) on the second stage butterfly valve makes the accelerator pedal "heavier" when this valve is opened.

Gasoline enters the float chamber (Section A) through the gasoline supply connection, passing through a strainer in order to prevent any particles of dirt being drawn into the carburetor. A settling well (Section A) is provided to catch any impurities which may pass through the strainer.

The level of the gasoline in the float chamber is maintained at a constant height by means of the float and the float valve. The height of this level is set at the factory and should not be changed. The gasoline is conducted from the float chamber through passages (Sections C and E) in the body of the carburetor up to the annular recess in the primary, or low speed throat, and to the annular recess in the high speed throat. From these points it is drawn into the body of the carburetor through the throat tubes (or jets).

The annular recesses in the throat also have connection with the body of the carburetor by means of air passages in the carburetor. When the engine is started the suction causes a rapid

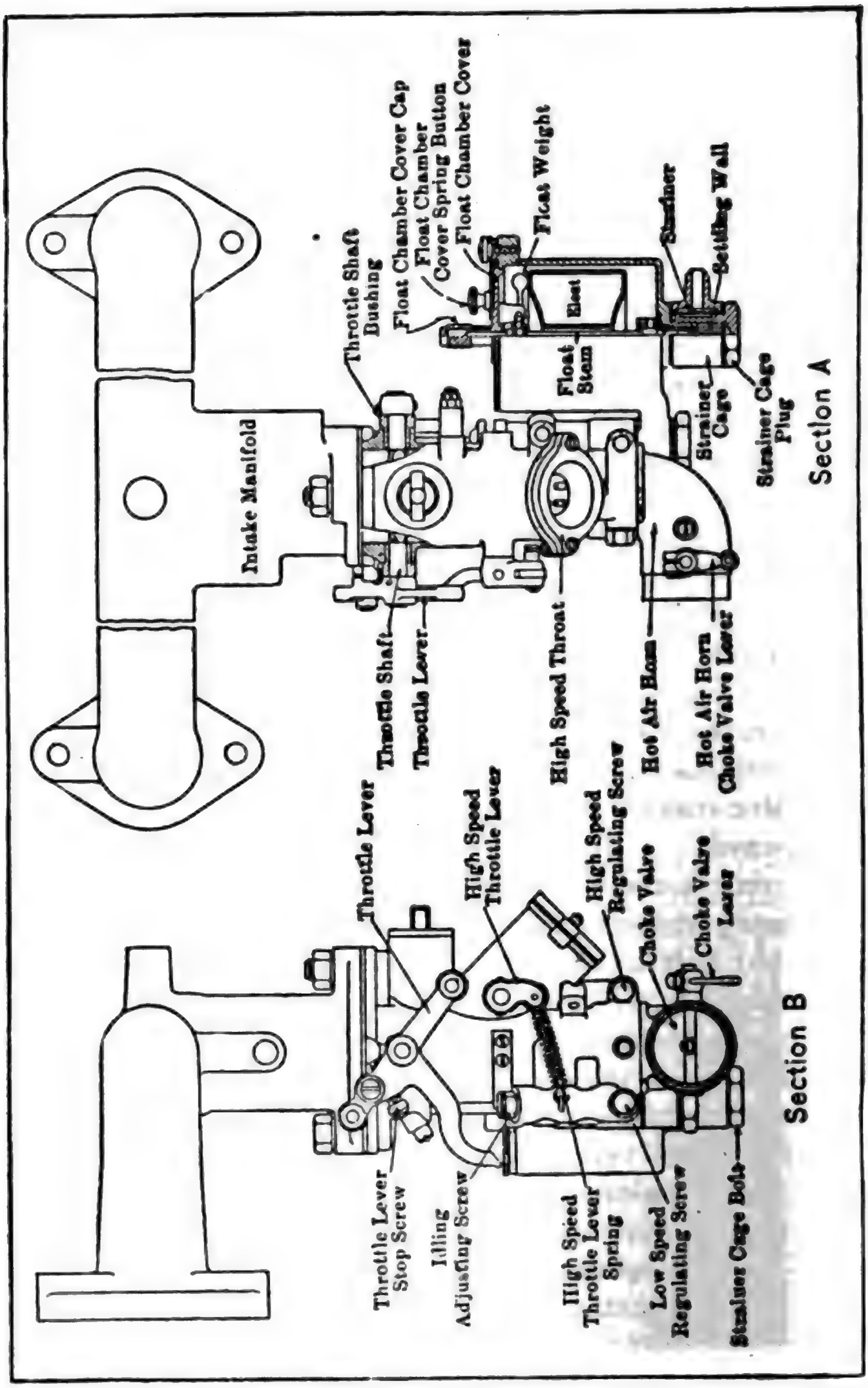

Throttle Shaft Bushing
Float Chamber Cover Cap
Float Chamber Cover Spring Button
Float Chamber Cover
Float Weight
Float
Strainer
Settling Wall
Float Stem
Strainer Cage
Strainer Cage Plug
Intake Manifold
Throttle Shaft
Throttle Lever
High Speed Throat
Hot Air Horn
Hot Air Horn Choke Valve Lever
Section A
Throttle Lever
High Speed Throttle Lever
High Speed Regulating Screw
Choke Valve
Choke Valve Lever
Throttle Lever Stop Screw
Idling Adjusting Screw
High Speed Throttle Lever Spring
Low Speed Regulating Screw
Strainer Cage Bolt
Section B

Fig. 398.—The Ball and Ball Carburetor Used on Riker Trucks Showing Important Parts.

passage of air through the throat and creates a suction in the throat jets, which draws both gasoline and air through the jets, so that the gasoline is thoroughly atomized and properly mixed with the air.

There is no action in the second stage until the valve opens; when this occurs the action is the same in principle as that described in the first stage, or low speed throat. The quantity of gasoline drawn through the throat jets, to give a correct mixture, is automatically regulated by the amount of suction created on the jets and by the metering screws (Sections B and E). Under no conditions should these regulating screws be changed, as they are carefully drilled to calibration.

A very simple and efficient accelerating device is used, as shown in Section D, to prevent a temporarily lean mixture when the throttle is opened suddenly for rapid acceleration. Gasoline stands in the pick-up cylinder to the height indicated. This cylinder is divided into two parts by a diaphragm through which passes a pick-up plunger. When running with the throttle only slightly opened a spring keeps the plunger up against the diaphragm; then, when the throttle is further opened, a roller and cam force the piston down in the cylinder. The gasoline is forced from the lower half of the cylinder into the upper half through a hole in the plunger rod. From the upper half of the cylinder the gasoline is drawn into the carburetor through the pick-up jet (this is shown by Section C) and enriches the mixture for acceleration.

An independent jet (Section C) is employed for idling. Its supply of gasoline is obtained through a tube from the idling well. Suction on this jet is created by not allowing the throttle valve to fully close, so that there is a passage of air over the jet. The quality of the mixture is adjusted by means of a screw which raises or lowers the "head" of gasoline in the well.

Adjustments of the Carburetor.—The permanent adjustments are made at the factory to suit the particular truck to which the device is fitted and should not be changed.

Adjustment No. 1

Air Choke for Starting.—This adjustment is to be used only for starting and "warming up" the engine.

The butterfly or choke valve (Section B) in the hot air horn

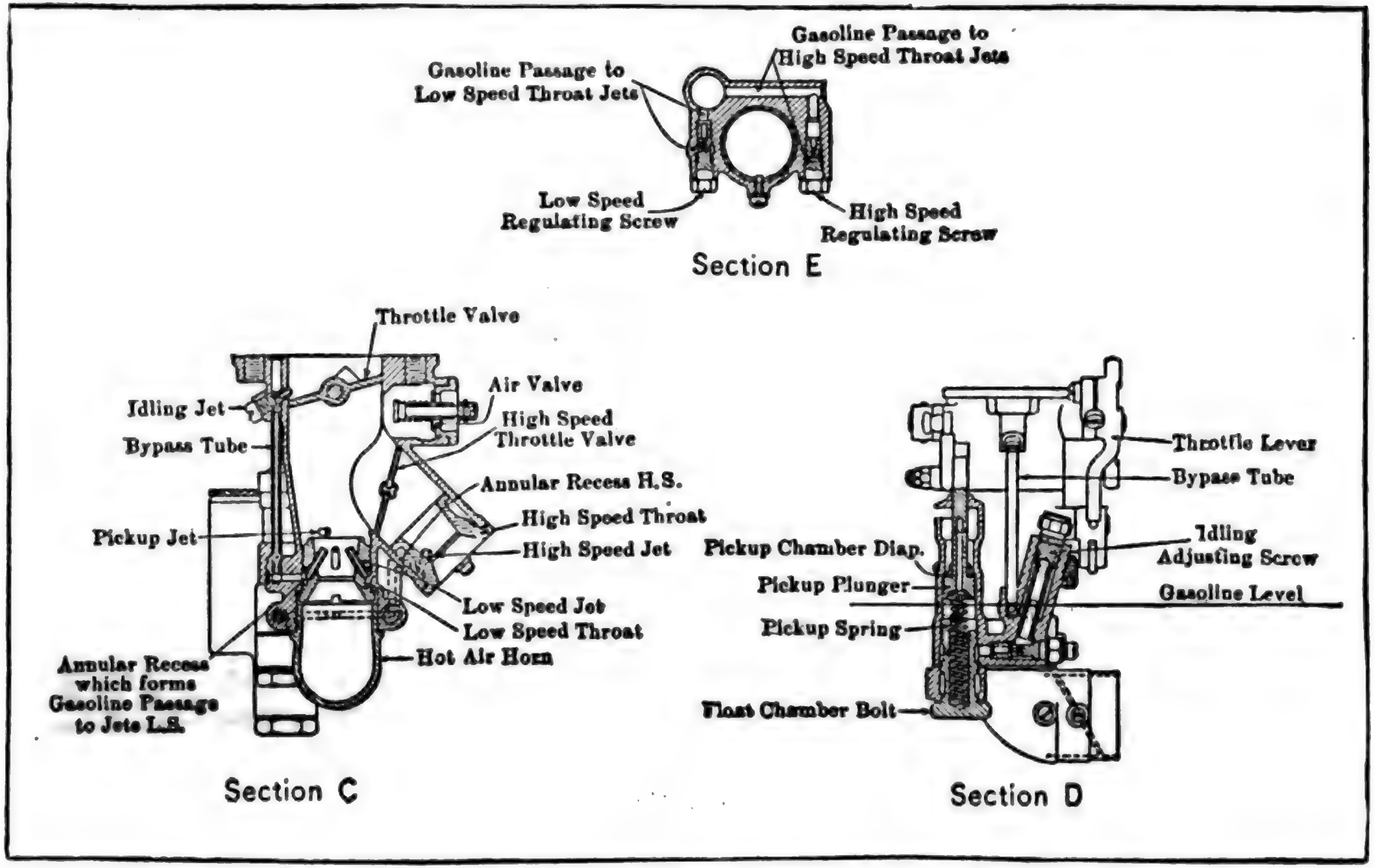

Gasoline Passage to High Speed Throat Jets
Gasoline Passage to Low Speed Throat Jets
Low Speed Regulating Screw
High Speed Regulating Screw
Section E
Throttle Valve
Air Valve
Idling Jet
High Speed Throttle Valve
Bypass Tube
Annular Recess H.S.
High Speed Throat
Pickup Jet
High Speed Jet
Low Speed Jet
Low Speed Throat
Hot Air Horn
Annular Recess which forms Gasoline Passage to Jets L.S.
Section C
Throttle Lever
Bypass Tube
Idling Adjusting Screw
Pickup Chamber Diap.
Pickup Plunger
Gasoline Level
Pickup Spring
Float Chamber Bolt
Section D

Fig. 399.—Sectional Views of Ball and Ball Carburetor Used on Riker Trucks.

(Section A) is connected to a small lever on the right side of the dash; moving the lever to the left closes the valve and to the right opens it.

When the engine is started the lever should be in its extreme left position. As soon as the engine is started move the lever to approximately its center position and allow it to remain there a few minutes. This will prevent the engine from backfiring until it becomes warm, and then cover the lever to the extreme right, which is the running position. Do not forget to move the lever to the right as soon as possible, because with it in any other position you cannot obtain the full engine power and best fuel economy. In cold weather it will be necessary to run longer with the lever towards the right, as more time is required to warm the motor.

Adjustment No. 2—To Set for Idling

(a) First: Set spark one-half advanced.

(b) Second: Adjust the throttle screw (Section B) to give approximately the desired idling speed. (Turn the screw to the right to increase the idling speed.)

(c) Third: Obtain the correct quality of mixture by means of the adjusting screw (Sections B and D). (Turn the screw to the left to enrich the mixture.)

Before making final adjustments allow the motor to become thoroughly warm.

Always allow the motor to run several minutes after changing the setting of the idling adjustment screw (Sections B and D), as a little time is required for a change in adjustment to take effect. It will probably be necessary to change adjustments (a) and (b) several times before the exact results are obtained. Idling with this carburetor is exceptionally good and any performance desired may be obtained by following the schedule of adjustments outlined above.

Adjustment No. 3—Hot and Cold Weather

The air which enters the carburetor through the hot air horn (Section A) is drawn from a sleeve around the exhaust pipe. As the temperature of this air should be lower in the summer than in the winter, a shutter is provided on the hot air intake pipe. In hot weather this should be entirely opened to allow cool air to be drawn into the carburetor.

It is impractical to set any fixed rule for the amount the shutter should be opened except that in extremely cold weather it should be sufficiently closed to prevent the carburetor from continually "popping."

Carburetor Troubles

Rich Mixture:

Indications:

Black smoke discharged from the exhaust.
Motor sluggish and slow to accelerate; this would be particularly noticeable when gears were changed on a hill and the motor failed to "take hold" on the lower gear.

Probable Causes:

(a) Air choke closed.
(b) Air entering the carburetor too hot.

Adjustments:

(a) Move dash lever to the extreme right position and see that the hot air horn butterfly or choke valve (Section B) is entirely open when the lever is in this position.
(b) Open the cold air shutter on the hot air intake horn.

Lean Mixture:

Indications:

Backfiring in the carburetor.
Firing in the muffler when descending hills with the clutch engaged.
Lack of power.

Probable Causes:

(a) Motor too cold.
(b) Air entering the carburetor too cold.

Adjustments:

(a) Move dash lever half way toward the left for a few minutes.

(b) Decrease the opening of the cold air shutter on the hot air intake horn.

Special Cases:

(a) The motor runs all right on both stages but acts extremely lean when running on the primary stage only.

(b) The motor still acts lean after having tried all adjustments for leanness.

(c) Gasoline overflows from the carburetor.

Adjustments:

(a) The second-stage butterfly spring (Section B) is probably broken or loose.

(b) Turn off the gasoline supply and remove the high and low speed regulating screws (Section B). Examine the regulating screw and blow out any particles of dirt found in the holes, but absolutely do not change the size of the holes in the regulating screws. Before replacing the regulating screws turn on the gasoline and allow the carburetor to flood for a few seconds.

(c) Tap the float chamber lightly with the hand, which will relieve the trouble if it is due to the float having become temporarily stuck. If this does not stop the trouble, remove the float and float valve by removing the float cap (Section A) and see that the valve and valve mechanism are in good condition. Drain the float chamber. Occasionally remove the strainer plug (Section A) from the carburetor float and allow gasoline to flush the settling chamber.

Maxwell Electrical Circuits.—The wiring diagram shown at Fig. 400 is designed to show diagrammatically both external and internal connections of the Truck Electrical System. It is drawn in such a manner that a small amount of study will show its relation to the actual wiring and outside connections of the truck as shown in the wiring diagram, Fig. 401. By studying these two wiring diagrams in connection with the explanations of the electrical circuits given below, it is possible for one to trace the electrical circuits for the ignition, lights, horn, and charging the storage battery.

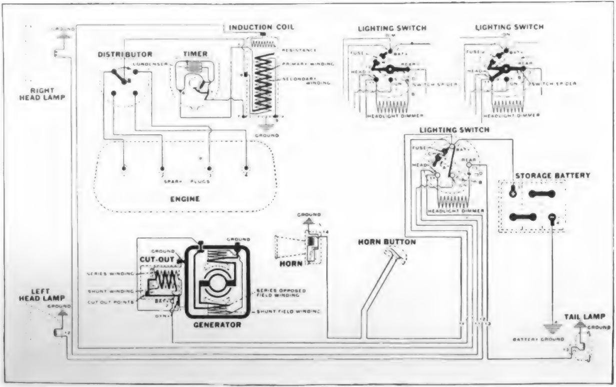

INDUCTION COIL
RESISTANCE
PRIMARY WINDING
SECONDARY WINDING
GROUND
DISTRIBUTOR
CONDENSER
TIMER
RIGHT HEAD LAMP
GROUND
SPARK PLUGS
ENGINE
LIGHTING SWITCH
FUSE
BAT.
REAR
HEAD
ON
SWITCH SPIDER
HEADLIGHT DIMMER
LIGHTING SWITCH
LIGHTING SWITCH
STORAGE BATTERY
HORN BUTTON
HORN
GROUND
GENERATOR
SERIES OPPOSED FIELD WINDING
SHUNT FIELD WINDING
CUT-OUT
SERIES WINDING
SHUNT WINDING
CUT OUT POINTS
BAT.
DYN.
LEFT HEAD LAMP
GROUND
TAIL LAMP
GROUND
BATTERY GROUND

Fig. 400.—Wiring Diagram of Maxwell Truck Electrical System.

Charging Circuit.—When the armature of the generator is not revolving, or is revolving at a very low rate, the cut-out points should be open. The cut-out is so designed that the cut-out points will not close until six volts is generated. If, after the cut-out points are once closed, the speed of the generator decreases so that it does not generate six volts, the cut-out points will automatically open the charging circuit and prevent the storage battery from discharging back through the generator.

When the armature of the generator revolves, a voltage is generated which causes current to flow through the shunt winding of the cut-out. As the speed of the armature increases, the voltage increases until at six volts the current flowing through the shunt winding is sufficient to cause the cut-out points to close. Closing of the cut-out points closes the charging circuit, the path of the charging current being as follows:

Starting at the positive terminal on the generator (terminal No. 1 on diagram), follow wire to terminal No. 1 marked "DYN +" on base of cut-out. From this point the current flows across the cut-out points and through the series winding to cut-out terminal No. 2 ("BAT +"). From this terminal follow circuit wire No. 2 to lighting switch terminal No. 2 ("BAT +"), to battery "+" terminal No. 3, through storage battery to battery "—", terminal No. 4, and to battery ground (No. 4) on truck frame. The current returns through truck frame to generator ground. From generator ground, the current flows through series opposed windings, energizing them, and back to generator terminal No. 1.

Regulation of the charging current is accomplished by the automatic action of the differential compound winding of the generator. The generator shunt field is opposed by the series field. If the generator speed varies from that necessary to produce six volts it will result in a slight variation in the charging current, which, through its action on the series winding, varies the generator magnetism in such a manner that the voltage, and consequently the charging current, will be kept practically constant.

Ignition Circuit.—When the switch key is inserted and turned in the lighting and ignition switch, it depresses the ignition switch contact spring and closes the ignition circuit by electrically connecting lighting switch terminal No. 2 (BAT+) with terminal No. 5 (IGN). For starting the engine, the ignition primary current is supplied by the storage battery. Its path can be traced as follows:

Starting at storage battery "+" terminal No. 3, current flows to lighting switch terminal No. 2 (BAT+), through ignition switch contact spring to terminal No. 5 (IGN), through circuit No. 5 to terminal No. 5 at the top of the induction coil. From terminal at the top of the coil, it flows through the resistance and primary winding to point No. 6 on the coil and to terminal No. 6 on the condenser cover at the timer. From terminal No. 6 on the condenser cover, the current flows through the condenser cover (shown in outline) to the timer breaker points and to point No. 7 through the contact breaker spring; from point No. 7 at breaker spring to ground point No. 7 at base of coil, through frame to battery ground point No. 4 and to battery "—" terminal No. 4.

After the engine has started and is turning the generator at a speed sufficient to close the cut-out points, primary current for ignition is supplied by the generator direct to lighting switch through circuit No. 2 to terminal No. 2 (BAT+). From switch terminal No. 2 the circuit is the same as outlined in the preceding paragraph except that the current returns to the generator instead of to the battery. Current is supplied by the battery only when the battery is not being charged.

A condenser is connected directly across the breaker points, and, while no current flows through it, it is an absolute necessity in order to get the proper performance of the induction coil.

At the instant the timer breaker points separate, a high tension current is induced in the secondary winding of the induction coil. This high tension current leaves the coil at terminal No. 8. Its circuit can be traced from terminal No. 8 on the coil to the center terminal No. 8 on the distributor cover where it is distributed to the separate spark plugs in the firing order of the cylinders. The high tension current jumps the spark plug gap to ground and returns to point No. 9, the grounded connection of the secondary winding.

Lighting Circuit.—The "OFF" position of the lighting switch spider is shown in dotted outline in the switch of the complete diagram (Fig. 400). In this position all the spider arms are free. The "DIM" and "ON" positions of the spider are shown in the diagrams of the lightning switch marked "DIM" and "ON," respectively. In the "DIM" and "ON" diagrams the spider arms which carry current are shown in full heavy lines.

When the generator is not running, the necessary current for lights is supplied by the battery. With lighting switch in "DIM" position, spider arms "A" and "D" connect contact point No. 10 with switch terminal No. 13 (REAR), and the lighting circuit is as follows:

Starting at the storage battery "+" terminal No. 3, trace circuit to lighting switch terminal No. 2 (BAT+), through the fuse to spider contact, point No. 10, through spider arms "A" and "D" to terminal No. 13 (REAR). From this point current for the tail lamp follows circuit No. 13 to the tail lamp and ground, the headlight current flowing through the headlight dimmer coil to terminal No. 11 (HEAD). From this terminal current follows circuit No. 11 to the right head lamp and ground and circuit No. 12 to the left head lamp and ground. From each of the lamp grounds, current follows the frame back to battery ground No. 4 and by cable to battery "—" No. 4.

With the lighting switch in the "ON" position, spider arms "A" and "C" connect switch contact point No. 10 with terminal No. 11 (HEAD) and spider arms "C" and "B" connect switch contact No. 10 with terminal No. 13 (REAR). The spider thus connects terminal No. 11 with switch contact No. 10, direct, and shunts the headlight current past the headlight dimmer coil. Current is supplied to contact point No. 10 as explained for the switch in "DIM" position, and is delivered to distributing arms "A" and "B" by spider arm "C." In the spider the current divides, that for the tail lamp going to terminal No. 13 (REAR) through spider arm "B," and that for the head lamps going to terminal No. 11 (HEAD) through spider arm "A." From terminals No. 13 and No. 11, the lighting circuits are the same as previously outlined for switch in "DIM" position.

When the generator is running and charging the storage battery, current for lights, as for ignition, is supplied by the generator to switch terminal No. 2 (BAT+) through circuit No. 2. From switch terminal No. 2 the circuits are the same as outlined except that the current returns to the generator instead of to the battery.

Horn Circuit.—Current for the horn is supplied, as for ignition and lights, by either the generator or battery, depending on the condition of the charging circuit. Beginning at switch terminal

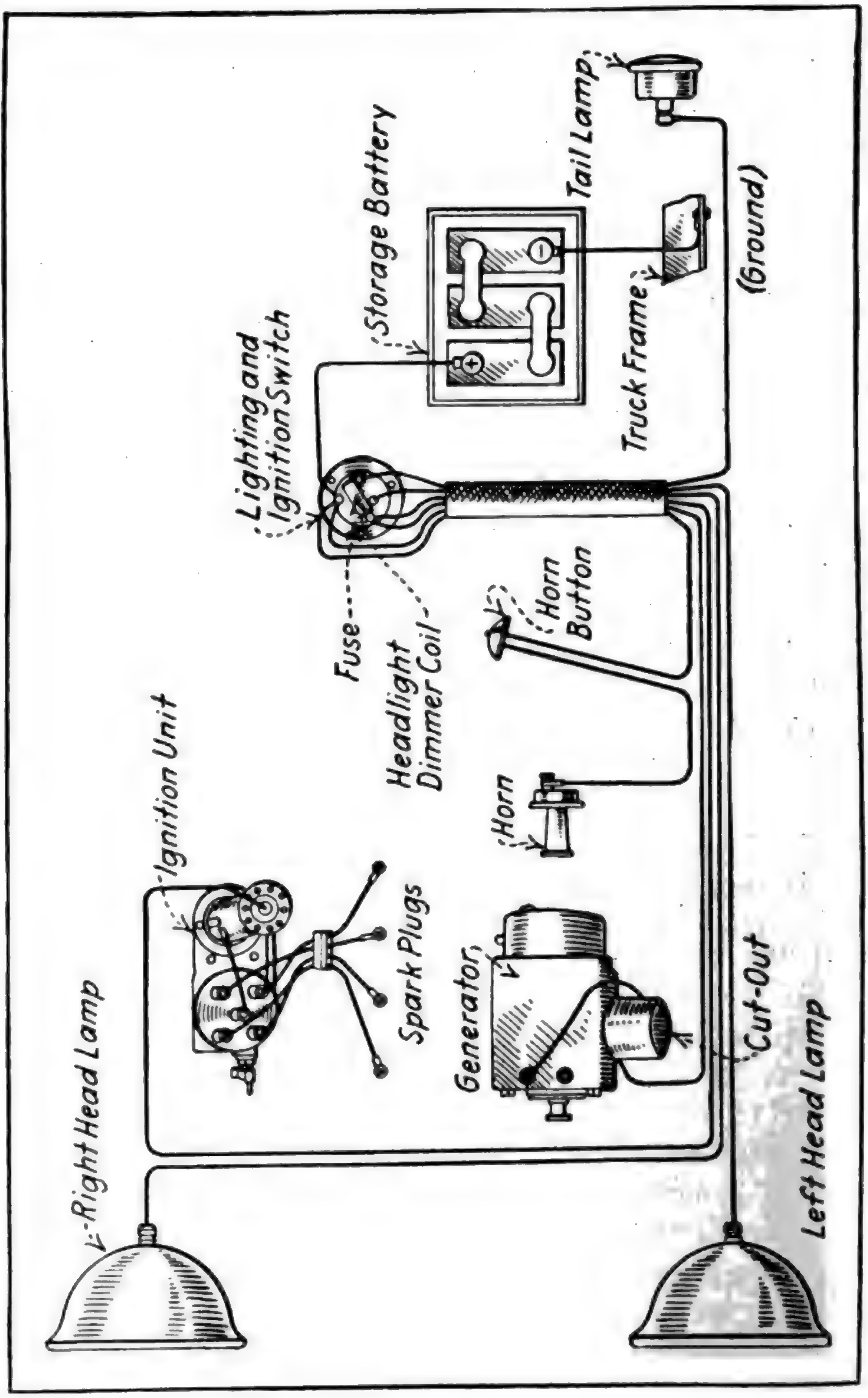

Tail Lamp
Storage Battery
(Ground)
Truck Frame
Lighting and Ignition Switch
Horn Button
Fuse
Headlight Dimmer Coil
Ignition Unit
Horn
Spark Plugs
Generator
Cut-Out
Right Head Lamp
Left Head Lamp

Fig. 401.—Wiring Diagram Showing Units of Maxwell Truck Electrical System.

No. 2 (BAT+), the horn circuit can be traced by following circuit No. 14, to horn button, through horn button to terminal No. 14 on horn, through horn magnet winding, across contact points to ground, and thence to source of current (generator or battery).

Reo Speed Wagon Electric System Ignition.—This truck is equipped with a combined generator, magneto-timer and distributor. So far as ignition is concerned, this machine is similar to the magneto previously used, the difference between the two machines being principally that the permanent magnets have been replaced by electro-magnets, enabling the machine to generate sufficient current to light and start the truck, as well as supplying the ignition current exactly in the same manner as when a magneto is used, and is running on the battery side. The coil, distributor and breaker are exactly the same as supplied on any high-class magneto, and require no more attention or different instructions for their care. A storage battery in which to store the current generated is an essential part of this system.

Ignition Switch.—The ignition switch is provided with a key to lock the switch lever in the off position in case the truck owner desires to leave the truck so that it cannot be started by unauthorized persons. The marking on the face of the switch, B-O-M, indicates the three points of the switch lever. When lever is turned to either the "B" or "M" position current is being supplied to the ignition system by the storage battery. "O" is the off position, in which the lever must always be left when the motor is not running.

Caution: Never leave switch lever on "B" or "M" side when the motor is standing still. It will discharge battery if you do. Always put switch lever in center on "O."

Magneto Breaker.—Inspection: By referring to cut at Fig. 402 the position of the circuit breaker can be seen. The distributor block forms the cover for the breaker box and is easily removed by unlatching the springs which hold it down and moving it to one side without unfastening the ignition cables. This allows the breaker and distributor mechanism to be seen. The distributor arm may be removed by pulling straight up. The breaker points should be kept flat and smooth, with contact the full width of points. A very fine file or fine emery cloth can be used to reduce any irregularity on contact points, being careful not to remove more material than is absolutely necessary. If points become badly worn or burned, they should be renewed.

Adjustment: The stationary breaker point is mounted on a screw which provides for adjustment of gap. The gap on high position of cam should be from .012-inch to .020-inch, and not more than .020-inch. The gauge attached to generator wrench included in tool-kit is .020-inch thick, which makes a good guide for this adjustment. The gap should not be varied outside of

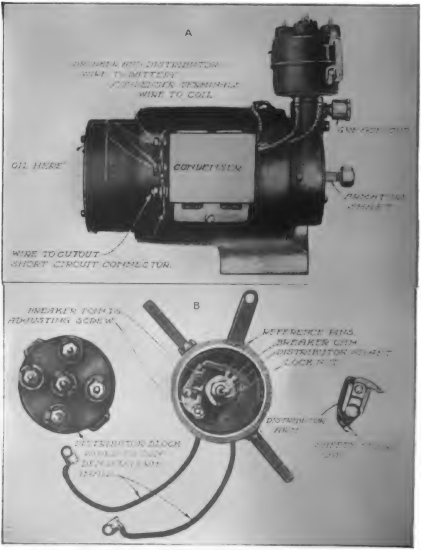

A
BREAKER AND DISTRIBUTOR
WIRE TO BATTERY
CONDENSER TERMINALS
WIRE TO COIL
GREASE CUP
OIL HERE
CONDENSER
ARMATURE SHAFT
WIRE TO CUTOUT
SHORT CIRCUIT CONNECTOR.
B
BREAKER POINTS ADJUSTING SCREW
REFERENCE PINS.
BREAKER CAM
DISTRIBUTOR SHAFT
LOCK NUT
DISTRIBUTOR ARM
DISTRIBUTOR BLOCK

Fig. 402.—Generator and Distributor Unit at A Used on Reo Speed Wagon. Top View of Make and Break or Timing Mechanism at B.

the above limits in order to alter the point of firing, as these limits are essential to a hot spark.

Ignition Timing.—Breaker and Distributor Setting: In case the generator is removed from motor and the relation between motor crankshaft and generator armature is disturbed, proceed as follows: Turn the motor over with all four petcocks open until pressure against the thumb hold over petcock number one indicates that compression is taking place in cylinder No. 1. Continue to turn about one-quarter turn more until the marks on face of flywheel (U.D.C. 1 and 4) are opposite reference mark on engine. Then, with the distributor block removed so as to allow the distributor arm to be seen, turn the armature shaft in either direction until the position of the distributor arm is the same as that shown on Fig. 403 with respect to the reference pin. Connecting up the universal joint with the generator armature shaft in this position will give the former timing.

To Check Point of Firing.—Open cylinder petcocks, retard spark control lever, turn on ignition switch and notice that the ammeter shows a discharge. Then while one person turns the motor over very slowly with the hand crank a second person can watch the ammeter. The instant at which the ammeter pointer starts to return to zero is the time at which the spark occurs. At this instant one of the U.D.C. marks on the flywheel should be opposite the D.C. reference point or not more than one-half inch before it.

To Correct Point of Firing.—In case the point of firing does not come between the above limits, it may be changed as follows without changing the position of the generator drive gears. Proceed as indicated under "Breaker and Distributor Setting" in order to get the crankshaft in the proper position for firing No. 1 cylinder. After removing the distributor block, the distributor arm may be easily taken off, by pulling directly up, giving access to the breaker cam which is held in place on the breaker shaft by the nut on its upper end. By removing this nut the cam can be loosened on the shaft, which is tapered, and its position with respect to the crankshaft can be varied as desired.

In resetting this cam, place it on its shaft so that the pin which is set in one side of the cam is in line with and between the center of the vertical shaft and the reference pin in the breaker case shown at B, Fig. 402. This is very necessary in

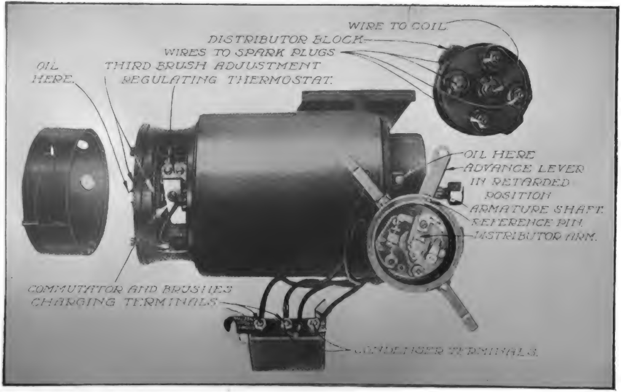

WIRE TO COIL
DISTRIBUTOR BLOCK
WIRES TO SPARK PLUGS
OIL HERE.
THIRD BRUSH ADJUSTMENT
REGULATING THERMOSTAT.
OIL HERE
ADVANCE LEVER IN RETARDED POSITION
ARMATURE SHAFT.
REFERENCE PIN.
DISTRIBUTOR ARM.
COMMUTATOR AND BRUSHES
CHARGING TERMINALS
CONDENSER TERMINALS.

Fig. 403.—Top View of Generator and Ignition Timing Unit Used on Reo Speed Wagon.

order that the distributor arm and block assemble in the proper relation to each other to give the spark to the right cylinder at the right time. Carefully check the new firing point, as indicated above, with the spark lever in the full retarded position, being certain it falls between the limits given.

Order of Firing.—The duty of the distributor is to deliver the spark to the different cylinders. The high tension wire connected to the spark plug for cylinder No. 1 should be attached to the distributor terminal which is directly above the locating notch in the edge of the distributor block. The terminals for the other cylinders follow in a clockwise direction in the order 1-3-4-2. The center terminal is for the high tension cable from the ignition coil.

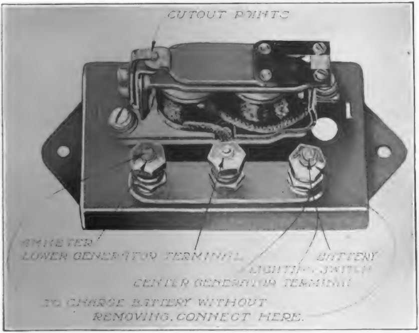

CUTOUT POINTS
AMMETER
LOWER GENERATOR TERMINAL
BATTERY
LIGHTING SWITCH
CENTER GENERATOR TERMINAL
TO CHARGE BATTERY WITHOUT
REMOVING, CONNECT HERE.

Fig. 404.—Automatic Cut-Out of Reo Speed Wagon Electrical System.

Coil.—The coil is mounted on the frame near the generator. There are no adjustments in connection with it other than to keep the terminals tight. A safety gap for the protection of the coil is provided on the distributor.

Spark Plugs.—Trouble that is laid to the ignition device is often due to incorrect adjustment of the spark plug gap. The correct gap is $\frac{1}{32}$ inch, and all the plugs should be set the same. Keep the porcelain and points clean to prevent misfiring.

Electrical Generator.—Lubrication: The illustrations at Figs. 402, A, and 403 show the combined generator and ignition device. Oil at each end of the armature with three or four drops of any good light oil each 1,000 miles. Keep the grease cup which lubricates the distributor shaft filled with any good heavy grease and give one turn each 500 miles. Do not flood the oilers or lubricate other parts of the generator. Keep the exterior free from oil or dirt, as there is danger of same working in causing short circuits.

Automatic Cut-out.—The automatic cut-out, which is shown at Fig. 404, is located on the dash beneath the hood and is for the purpose of preventing current from the storage battery flowing back through the generator when it is standing still or running at a high speed lower than 300 r.p.m. or about seven miles per hour in high gear. It acts as a check valve, allowing the current to flow in one direction only, from the generator to the battery and not from the battery through the generator. The cut-out requires no adjustment other than to keep the points clean and smooth, with contact the full widths. Do not under any condition alter the spring tension.

Caution: Do not close the cut-out points when the motor is not running, as they will stick together and allow the battery to be discharged in a few hours' time, as well as ruining the cut-out coil.

Regulation of Output.—This generator is equipped with "third brush regulation" and means is provided for varying the maximum output. A small screw which is located in the rear end of the generator is connected to the third brush by a rack and pinion movement which allows the position of the brush on the commutator to be changed slightly. Turning this screw in a clockwise direction increases the output for a given speed, while turning it in the opposite direction decreases it.

Thermostatic Control.—In order to provide against a shortage of current in winter weather or on short runs where starts are numerous, and at the same time to insure against overheating the generator in the summer or on long runs, a thermostat is arranged to cut down the charging rate as soon as the temperature of the generator reaches a certain point. This thermostat can be seen by removing the cover from the rear of the generator and since it requires no adjustment should not be tampered with.

Amount of Charge.—The generator is in normal working condition if the ammeter shows a charge of about 12 amperes when running 15 miles per hour on first starting and reduces this charge to about six amperes on becoming warmed up.

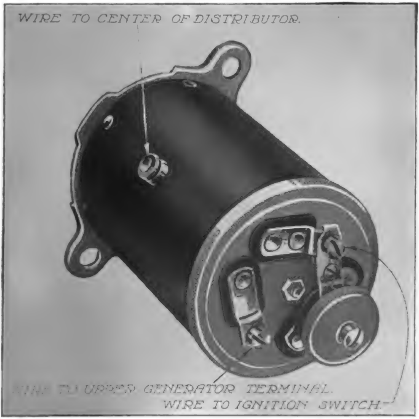

WIRE TO CENTER OF DISTRIBUTOR.
WIRE TO UPPER GENERATOR TERMINAL.
WIRE TO IGNITION SWITCH.

Fig. 405.—Ignition Coil Used on Reo Speed Wagon.

Condenser.—The condenser is contained in the metal box mounted on the side of the generator. This places it within a few inches of the breaker points, which is very desirable. The condenser terminals are the two upper ones on the end of the box. The two lower terminals are connected to the armature and the clip marked "Short Circuit Connector" is for the purpose of connecting these terminals if it is desired at any time to run the motor without generating current.

Commutator.—Commutator surface should be clean and bright, and if found to be blackened or rough, polish and smooth down with fine (00) sandpaper. Armature should be rotated during this process. NEVER USE EMERY CLOTH FOR THIS PURPOSE. After cleaning commutator as above, carefully blow out all sediment from the commutator and generator case. Avoid the use of all commutator compounds.

Brushes.—The brushes are of special copper carbon composition and should last indefinitely. If replacement should be necessary from any cause, do not use carbon substitutes, but obtain the special brushes furnished by the Remy factory, branch house or service station. Brushes should be kept tight on the holders and in perfect contact with the commutator.

Caution: Under average conditions the generator will perform its work without attention other than oiling and, until it fails to work properly, should be left strictly alone, and even then should be adjusted only by a mechanic who is familiar with such work.

Ammeter.—The ammeter is for the purpose of indicating the amount of current passing into and out of the storage battery. The indicator or hand should point to zero at the center of the scale when the motor is standing still and all lighting or ignition switches are in the "off" position. If it does not, it is almost conclusive proof that there is a leakage of current tending to run down the battery, but in order to make certain that the ammeter is not at fault, disconnect one of the battery terminals at the battery. This prevents any current from flowing and the ammeter will, if it is all right, indicate zero or very closely to it. If the ammeter indicator is off from this zero position, then the difficulty is in the ammeter and it may be corrected by removing the ammeter from the case and resetting by bending the hand. There is very little chance of this type of ammeter reading incorrectly, as ordinary short circuits have little or no detrimental effect, since only a small part of the current is shunted through the coil attached to the indicator, and this current does not affect the permanent agent. However, an unusually heavy short circuit will burn the coil or balancing springs.

Leakage.—If the ammeter shows zero reading with the battery disconnected and shows a discharge reading with battery connected, motor standing still and all switches in the off position, then there is a leakage of current. This leak should be found and stopped at once or the storage battery will become discharged, and if allowed to remain in this condition for any length of time, cause injury to the battery. These leaks are most likely to be found in the lighting wires, sockets and connections and in the ignition wires. Leaks in that section of wires between ammeter and battery are not registered on the ammeter, which should be borne in mind when looking for battery trouble.

The ammeter does not show the amount of current used by the starting motor. The starting motor takes about 95 amperes to turn the engine over at approximately 125 revolutions per minute. This current is used, of course, only for a few seconds, and it is not considered necessary or advisable to try to pass it through the ammeter.

The ammeter does not show the amount of current in the battery. A hydrometer is the only instrument that will show this.

Starting Motor.—This is a small six-volt electric motor from which the power is transmitted to the transmission main shaft by means of a chain and sprockets in combination with two gears contained in an oiltight case on the end of the starting motor case. This is shown at Fig. 406.

The starting motor requires very little care other than oiling. An oil hole is provided for each end of the armature shaft and each should be given a few drops of light oil every 1,000 miles. The gearcase is packed with heavy grease and a removable plug provides a means of replenishing it, although this will not be necessary often than once a year. The commutator should be cleaned by an experienced person about once a year. The removable band makes it easily accessible. The instructions given for the care of the generator commutator apply to that on the starting motor also.

Starter Mechanism.—To operate: First, see that the gear shifting lever is in the neutral position and the clutch pedal released or in the driving position. Second, see that the spark lever on the steering column is in the retarded position and the throttle lever slightly advanced. Then with the ignition switch on "B" or "M" push downward on the starting button, which is located in front of the gear shifting lever. This throws the electric switch, which is situated beside the starting motor, into contact and allows the current from the storage battery to flow

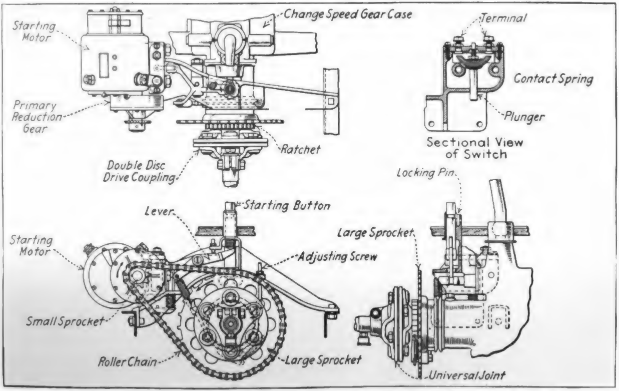

Starting Motor
Change Speed Gear Case
Terminal
Contact Spring
Primary Reduction Gear
Plunger
Sectional View of Switch
Ratchet
Double Disc Drive Coupling
Locking Pin
Starting Button
Lever
Large Sprocket
Starting Motor
Adjusting Screw
Small Sprocket
Roller Chain
Large Sprocket
Universal Joint

Fig. 406.—How Starting Motor of Reo Speed Wagon Electrical System is Installed.

through the starting motor, causing it to spin the gasoline motor in the car until it starts on its own power. The pressure on the starting button must then be released, allowing it to return to its original position, thus stopping the starting motor. The starting button is so arranged that it cannot be pressed down unless the gear shifting lever is in the neutral position. This prevents running the truck by means of the starter, which is very harmful to the storage battery.

To Lock the Truck.—If the starting button be pressed half way down a padlock may be fastened around the locking pin shown in Fig. 406. When this is done it prevents shifting the gears from the neutral position, the floor boards cannot be removed, and the starter cannot be used.

Mechanism.—The switch and mechanism are plainly shown in small cut at Fig. 406, A. When the button is pressed down, the lever pulls up the switch plunger by means of the lifter. This closes the electric circuit through the storage battery and starting motor by means of the contact brush in the switch. At the same time the lever tightens the friction cable, which tends to hold the sheave until the trip pin comes in contact with the side of slot provided in the sheave. When the trip pin makes this contact the pawl is twisted and brought in mesh with the teeth on the ratchet. With the ratchet in this position the starter sprocket and universal shaft revolve as a unit driven by the starter by means of the chain.

When the foot button is released the sheave is free, which relieves the pressure against the trip pin, allowing the spring to disengage the ratchet pawl. At the same time the switch plunger opening spring opens the starter switch. Should the contact points become burned after long use any irregularity may be removed by a fine file or emery cloth. A screw and lock nut provides adjustment to take up any wear on the contact points.

The adjusting screw gives an adjustment to take up any stretch in the friction cable or spring. Need of adjustment is indicated by the starting motor running without turning the universal shaft or by starting to turn it with a severe pound caused by the ratchet pawl not engaging as quickly as it should. Adjust the cable so that when released it will allow the sheave to be free to turn and at the same time have just enough tension when engaged to cause sufficient retarding action on the sheave to trip the ratchet pawl immediately when the starting motor starts to run.

If motor fails to start, look for some loose connection or poor contact. If the battery is run down, it can be easily ascertained by turning on the lights. If they burn very dim it shows that the battery is down. It is often possible to start the motor by hand cranking even if the battery is too low to burn the lights bright.

Lighting Switch and Lamps.—The lighting switch shown at Fig. 407 is arranged to give bright or dim bead lights, the side lights being dispensed with and the dim lights taking their place. The headlights are dimmed by being connected in series or in such manner that the current is caused to pass first through one lamp and then through the other; this cuts down the amount

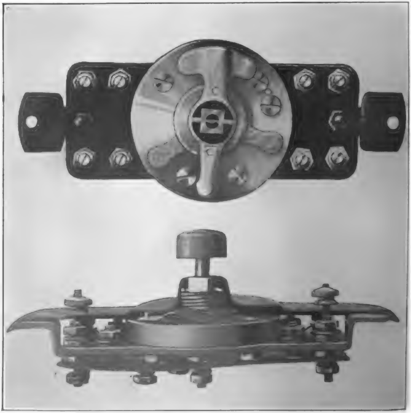


Fig. 407.—Lighting Switch Used on Reo Speed Wagon.

of current passing through both of the lamps and consequently they burn lower than their full candlepower, giving a dim and non-glaring light.

When the switch lever is on bright, then the current flows directly to each lamp and the full candlepower of each lamp is obtained.

It is advisable to use the dim lights as much as possible and it will be found that they are ample for city driving.

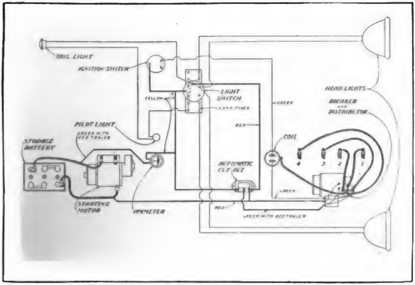

TAIL LIGHT
IGNITION SWITCH
YELLOW
LIGHT SWITCH
LAMP FUSES
GREEN
HEAD LIGHTS
BREAKER AND DISTRIBUTOR
RED
PILOT LIGHT
GREEN WITH RED TRACER
STORAGE BATTERY
COIL
AUTOMATIC CUT-OUT
4
3
2
1
GREEN
STARTING MOTOR
AMMETER
RED
GREEN WITH RED TRACER

Fig. 408.—Wiring Diagram of Reo Speed Wagon Electrical System.

The use of dim lights saves the current from the storage battery and also prolongs the life of the lamp. If one of the lamps should become broken or disconnected when burning on the dim side, the other lamp will go out also, making it necessary to throw the switch to the bright side. This will show which lamp is injured, the good lamp burning up to its full power. Use 6-8 volt 15 candlepower Mazda lamps.

The tail and instrument lights are connected in series. Should the tail light go out, the instrument light will go out also, showing the driver at all times whether the tail light is burning or not. If one of the lights goes out, the defective lamp may be found by removing one at a time, and replacing with a lamp which is known to be right. Use 3-4 volt 3 candlepower Mazda lamps. It is necessary that these lamps be of the same voltage and candlepower, and it is advisable to have the same make of lamps, otherwise one may burn brighter than the other.

The tail and instrument lights are connected to the lighting switch in such a manner as to be turned on when either the bright or dim headlights are lighted, requiring no separate operation for the tail and instrument lights.

Fuses.—A fuse for each headlight and one for the tail and instrument lights are provided in the lighting switch, as shown in wiring diagram at Fig. 408. Common five-ampere wire should be used in replacing fuses.

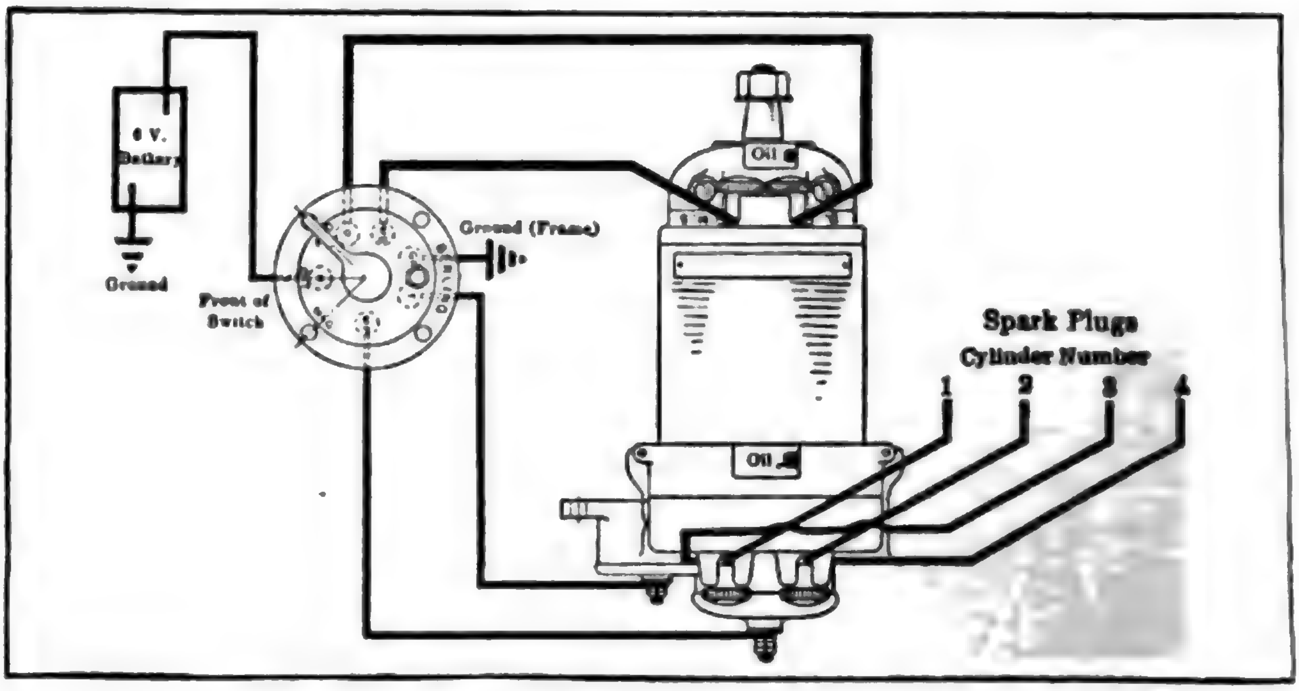


Fig. 409.—Magneto Ignition of Riker Truck.

Riker Ignition System.—The dual type of magneto ignition is used. The magneto is the standard high tension type with a standard combination dash coil and switch. Fig. 409 shows the wiring connections between the battery, coil magneto and spark plugs. The current for the battery ignition is supplied by a storage battery suspended from the frame at the left side of the cab. For instructions concerning the care of the battery see instructions in this chapter.

Magneto Settings.—The magneto is set so that with the spark fully advanced ignition takes place when the piston is $5/16$ inch below the top of its travel on the compression stroke. When the spark is fully retarded, ignition occurs with the piston slightly past top center and descending. The interrupter or breaker oints should be adjusted so that a maximum gap of .35 m.m. s obtained (the thickness of flat piece of steel on magneto adusting wrench). The points will not require adjustment more ften than once a year.

MAINTENANCE

Oiling.—It is most important that the magneto be both reguarly and correctly oiled. Each oil cup should be given several lrops of "Three-in-One" oil every 1,000 miles. Do not overoil.

Cleaning.—The contact points of both the magneto and batery breaker and the entire breaker mechanism should be thorughly cleaned with gasoline as often as they accumulate any oil r dust. The inside of the distributor plate and the collector ing should likewise be cleaned occasionally with a cloth noistened with gasoline. All parts should be allowed to dry efore attempting to run.

The Coil.—A combination coil and switch is used. The switch as three positions—"Mag.," "Off." and "Bat." The "Bat." poition should be used for starting, and as soon as the motor peeds up the lever should be thrown over to the "Mag." poition. If, however, the magneto should fail, the coil is so esigned that the motor may be run on the battery until the agneto can be fixed.

Spark Plugs.—The spark plugs should be examined and leaned regularly and the points adjusted so that a gap of aproximately .028 is obtained.

The condition of the porcelain on the portion of the plug exosed to the explosive mixture is a fair indication of the quality f the mixture.

If the plugs are sooty, the mixture is rich; but if the sooty eposit is greasy, it shows that the engine is getting excessive brication.

Ignition Troubles.—In case the motor misfires or refuses to tart and the ignition is suspected, the spark plugs and wiring ould be examined first.

See that the gaps are correctly set and clean the plugs.

Check the wiring by the above diagram and make sure the ring order is correct.

Examine all wiring for "grounds."

In case the trouble is not located in the wiring the magneto

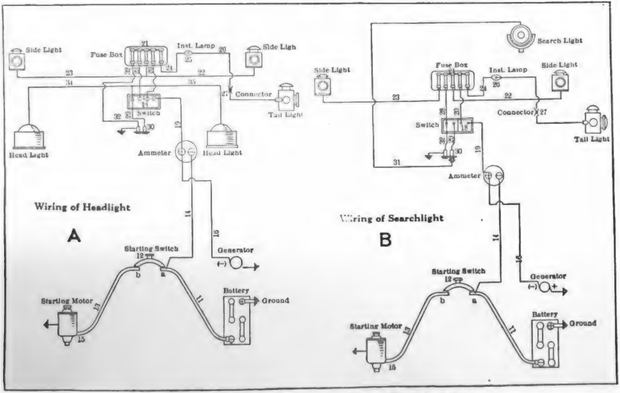

Side Light
Fuse Box
21
Inst. Lamp
25
20
Side Ligh
23
24
22
34
35
27
Connector
Tail Light
32
Switch
30
19
Head Light
Ammeter
Head Light
Wiring of Headlight
A
14
16
Starting Switch
12
b
a
Generator
(-)
Starting Motor
13
11
Battery
Ground
15
Search Light
Side Light
Fuse Box
Inst. Lamp
26
Side Light
23
24
22
Connector
27
Tail Light
33
Switch
18
31
30
19
Ammeter
Wiring of Searchlight
B
14
16
Starting Switch
12
b
a
Generator
(-)
+
Starting Motor
13
11
Battery
Ground
15

Fig. 410.—Wiring Diagrams Showing Riker Electrical System.

hould either be sent to a Locomobile Service Station or one f Magneto Manufacturers' Service Stations.

Riker Electric Equipment.—The electrical system is of the hree-unit type, and consists of a generator, a starting motor nd a dual magneto. The same storage battery is used for tarting, lighting and in the ignition system. The "ground-eturn" system of wiring is used and all wires except connecions between instruments on the dash-board are carried in exible metal conduit, both for protection and as an additional ground" for the return circuit. The connectors are so designed hat the current does not pass through the springs in them, and akelite insulation is used both because of its strength and heat-esisting qualities.

Wiring.—In the following description of the wiring the numers used apply to all figures. The positive terminal of the batery (marked +) and shown at Fig. 410 is grounded by a short ad to a terminal block on the frame. From the negative termial of the battery (—) lead No. 11 passes along the frame, then up nd across the dash-board to terminal (a) of the starting switch No. 12). The starting motor lead, No. 13, passes from the ther starting switch terminal (b) back across the dash-board hown at Fig. 411, parallel to lead No. 11, and then down to the tarting motor terminal, No. 15. The other side of the starting otor is grounded within the motor assembly. This completes he starting circuit so that when starting switch button is deressed the current flows along wires Nos. 11 and 13 and enerizes the electro-magnet of the automatic pinion shaft. A short-ircuited coil of the field poles causes the starting motor to turn lowly as it shifts the gears into mesh and then rapidly picks p speed and cranks the engine. After the engine commences fire the current used by the starting motor falls off rapidly nd as the electro-magnet is in series with the motor it loses s excitation and a disengaging spring overcomes its pull and ushes the gear out of mesh.

Generator-Battery Circuit.—The positive side of the generator s grounded. Lead No. 16 passes back of the frame side member o the dash and up and across the dash (Fig. 411) to the positive +) terminal of the ammeter. The negative (—) terminal of he ammeter is connected by a short lead, No. 14, on the dash o terminal (a) of the starting switch, which is always connected o the battery. (When a starting motor is not used, lead No.

14 runs directly from the ammeter negative (—) to the battery negative (—) terminal. The feeder for the lights is taken from the positive (+) ammeter terminal.

The purpose of the automatic cut-in switch is to disconnect the battery from the generator when the generator is either not operating or when its voltage is less than that of the battery and prevents the battery from discharging through the generator when the truck is standing. It is so constructed that when the voltage of the generator becomes greater than that of the battery, about 500 r.p.m. engine speed, the switch automatically "cuts-in" and the generator charges the battery, then when the engine is slowed down to about 450 r.p.m., the switch "cuts-out" and disconnects the generator from the battery. The cut-out speed is made slower than the cut-in speed so that it will not be constantly opening and closing when the truck is being operated at the cut-in speed.

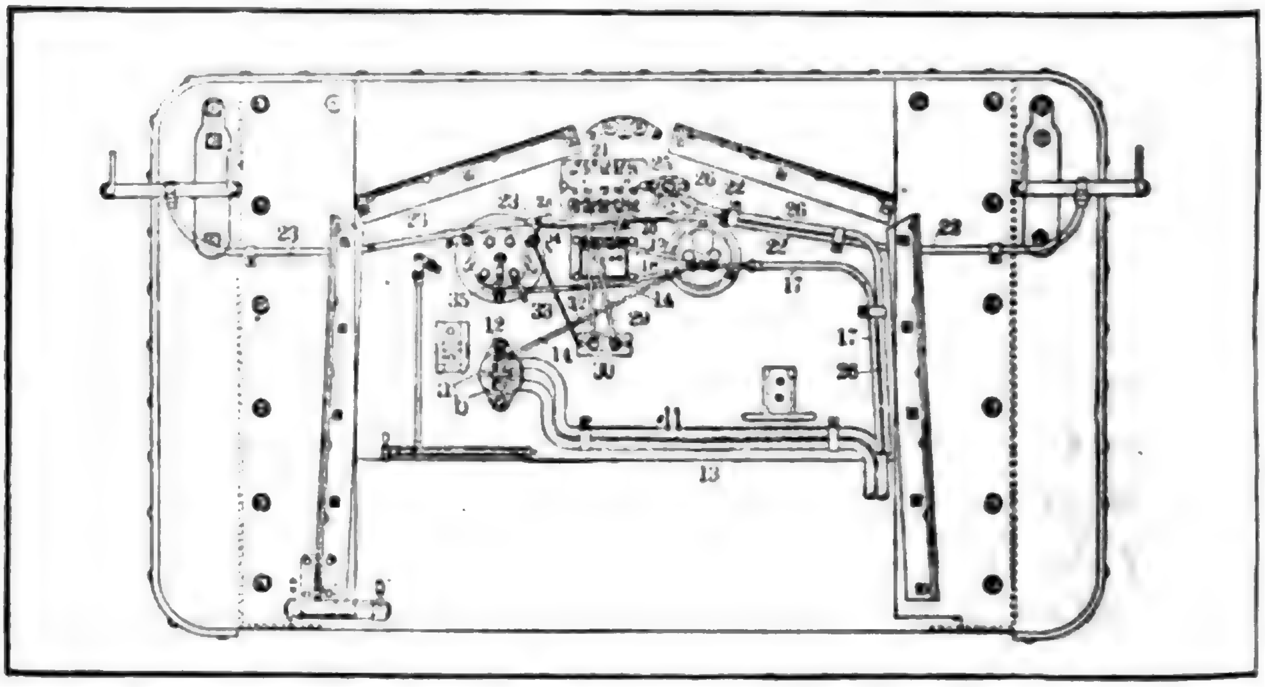


Fig. 411.—How Wiring is Arranged on Dash of Riker Truck.

Light Circuits.—All lights are controlled by the two-gang switch, No. 18. The dash lead, No. 19, from the positive (+) ammeter terminal to one terminal of the left switch (as viewed from the engine side of dash) forms the main feeder. The other terminal of this switch is connected by wire No. 20 to the common busbar terminal of the fuse box No. 21 and is the feeder for all the fuses. The side-light leads Nos. 22 and 23 start from separate fuses and pass across the dash to the side lamps. The dash instrument lamp No. 25 is connected in series with the tail lamp.

Wire No. 24 runs from the tail-light fuse terminal to one of the holding screws of the instrument lamp. From the center terminal on the instrument lamp, lead No. 26 passes across the dash and then down to the frame side member and back to the tail lamp.

A connector, No. 27, is provided where this lead is first attached to the frame side member so that the dash may be removed without removing the entire lead. The right-hand switch is connected in series with one socket of the search and trouble lamp socket unit No. 30 by wire No. 28 from the fuse box to the switch and by wire No. 29 from the switch to the searchlight and trouble lamp socket unit. The searchlight is connected by a flexible cord and plug, No. 31, to this socket; the other socket of the searchlight and trouble lamp socket unit is connected by wire No. 32 to the live terminal of the switch. With this arrangement of wiring all lights are controlled by the left-hand switch (viewed from the driver's seat); the other switch is provided so that the searchlight may be turned off without affecting the other lights or the trouble light socket.

Fig. 410, A, shows the wiring arrangement when headlights are used in place of the searchlight. The wiring is the same as the standard, except that both side light leads No. 22 and 23 are connected to the same fuse box terminal, both headlight leads Nos. 34 and 35 are connected to one terminal of the left-hand switch and the trouble lamp is connected directly to a fuse terminal.

Ground Wires.—The ground return circuits for the trouble and searchlight socket and side lights are made by the bare copper wires Nos. 33 and 34 on the backing plate of the ignition plate, which is grounded by a lead directly on to the motor.

Generator Drive and Support.—The generator is carried in a cradle on the left side of the engine crankcase and driven by the pump shaft. It may be removed by connecting the flexible couple between it and the pump shaft and loosening the holding strap. The construction of this generator is exceedingly strong and is so designed that it should only be necessary to oil regularly and examine the brushes.

Commutator and Brushes.—Examine the commutator occasionally by removing the pressed steel collar over the brushes. Keep the commutator free from dirt or oil. When dirty, clean with a cloth (not waste). If the commutator is found to be rough, smooth with fine sandpaper, but do not use emery cloth. The brushes should not be removed except in case of trouble. To remove brushes disconnect the leads and raise the springs which rest on the top of the brushes.

If it should be necessary to install new brushes, they should be obtained from the Hares Motors Service Department or the manufacturer of the generator, and when new brushes are installed care should be taken to see that they have a good bearing fit over their entire surface on the commutator. To obtain a good fit grind them in by using sandpaper under the brush. The oilers at each end of the generator should be given three or four drops of the best quality light oil once every month.

Starting Motor.—The starting motor is a No. 775 Frame Westinghouse. It is a series type motor fitted with an automatic electro-magnetic pinion shaft. Examine the commutator occasionally by removing the spring collar over the brushes and clean in the same manner as described for the generator.

Do not remove the brushes unless it is necessary. To remove brushes, lift the spring that holds the brush in the guide and take out the screw which holds the brush shunt, then the brush may be slipped out. When the brushes are removed they should be replaced in their original holder with the proper side up and, if necessary, should be ground in as described for generator brushes.

Examine the wire connection on the motor occasionally and see that it is kept tight. Also examine the splined shaft and keep it as clean as possible so that the pinion will shift freely.

To Remove Motor.—The starting motor may be removed by loosening the clamp bolts on the bracket and slipping the motor out. Care should be taken when replacing the motor to make sure that the pinion will mesh freely to a proper depth. The oil cup at each end of the motor should be given three or four drops of a good light machine oil every month. Give the splined shaft a few drops of engine oil occasionally.

LIGHTING AND STARTING SYSTEM

Delco Faults.—1. If starter, lights and horn all fail, the trouble is in the storage battery or its connections, such as a loose or corroded connection or a broken battery jar. 2. If the lights, horn and ignition are all O.K., but the starter fails to crank, the trouble is in the motor generator, such as dirt or grease on the motor commutator, or the motor brush not dropping on the commutator. 3. If the starter fails to crank or cranks very slowly, and the lights go out or get very dim while cranking, it indicates a loose or corroded connection on the storage battery, or a nearly depleted storage battery.

If the ignition system fails, and the supply of current from the storage battery is O.K., the trouble must be in the coil, resistance unit, timer contacts or condenser.

TWO-UNIT SYSTEM

In event of trouble, most makers recommend a careful study of the symptoms, which will usually provide a guide to find the component at fault. The indicator or amperemeter on the dash shows positively any failure of the generator or any break in the wiring. If the indicator does not indicate "charge" when the engine is speeded up but shows "discharge" when lights are turned on and the engine at rest, the dynamo or current regulator is not working properly.

A common trouble is the dynamo brushes not sliding freely in their holders. If the dynamo is driven by friction belt, this may be too loose to drive the dynamo at proper speed.

If the indicator does not indicate "charge" with the engine speeded up and does not indicate "discharge" with the lights on and the engine at rest, one should look for an open circuit or loose connection in the battery wiring or for corrosion or looseness in the storage battery terminals. Sometimes the dynamo terminals may have loosened and imperfect contact exist at this point.

Should the indicator show "discharge" with the lights turned off and engine at rest (providing that the indicator pointer is not bent), the insulation on lamp wires may be injured, this permitting contact with the frame, causing a short circuit. If the indicator indicates "charge" with the engine at rest, it is a positive indication that the pointer is bent.

If the charge indications are below normal with the engine running, it may be on account of slipping of the belt if the dynamo is driven in that manner, or because of poor adjustment of the current output governor.

If the ammeter "discharge" indications are above normal it is a sign that the lamp load is excessive or one of the lamp wires is in contact with the frame.

When the indicator pointer jerks from one reading to another with engine running at constant speed on the discharge scale, it means either a short circuit in the system or a loose terminal.

If trouble is experienced from fuses burning out repeatedly, it is a sign that the lamp wires are in contact with the frame at some point or that one of the lamps is defective because of a short circuited filament.

If the starting motor does not rotate, the battery may be discharged, the starting switch may not be making good contact or a motor brush may not make good contact with the commutator. There may be an open circuit in the battery wiring to the motor, or there may be a poor circuit or contact because of corroded battery terminals.

If the starting motor rotates but does not crank the engine, it is a sign that the overrunning clutch does not work properly or that the automatic shift starter pinion is not properly meshed with the flywheel gear.

If the lamps will not light but the starter cranks the engine, this shows that the storage battery is in proper condition and that the trouble is due to burned out or broken lamp filament or defective lamp fuses.

If the lamps burn brightly but fail to illuminate the road sufficiently, the bulbs may be out of focus in respect to the parabolic reflector of the lamp or the lamp supports may be bent in such a way that the rays of light may be directed too far upwards.

If the lamps burn dimly or not at all and it is difficult to crank the engine with the starting motor, this means a weak or discharged storage battery. In addition to this, the lamps may be old and have blackened insides, the system might be slightly short-circuited, or considerable resistance may be present, due to loose or dirty connections.

If the lamps blacken or burn out quickly they are not of the proper quality if they are six-volt lamps, and not of the proper voltage if other than six-volt lamps, providing the system is a six-volt, as most systems are. There is one exception to this rule, and that is the bulbs of the tail lamp and dash light, which are three-volt lamps when these two are wired together in series.

Burning out of the lamps may be caused by the voltage regulator not working properly, and if this is the case the lamps will burn out at high engine speed.

If the lamps flicker and the ammeter or indicator needle is unsteady, look for loose connections in the light wires, loose connections between battery and dynamo, loose contact at a lamp connector or lamp bulb, poor contact between fuses and fuse clips, or an exposed wire touching the frame intermittently.

USE OF TEST LAMP

If one suspects that the battery is discharged, its condition may be readily determined by using a lamp. The test lamp may also be used for locating short-circuits or open circuits. It is well to bear in mind that the lead terminals of the battery should be scraped clean and bright at the point where the test lamp wires bear in order to insure a good clean contact.

If the test lamp burns brightly it shows that there is current in the storage battery. To locate a short-circuit the fuses are removed from the rear of the switch and the wire is disconnected from the negative battery terminal. Connect one of the test lamp terminals to the free battery terminal and touch the other test lamp wire to the frame of the car. The test lamp should light if good contact is made, this indicating that the positive battery terminal is properly connected to the ground.

Keep one test lamp wire in contact with the negative terminal and touch the other wire to the end of the battery wire just disconnected. If the test lamp lights it shows that a conductor or wire connected to the battery, lamps, horn or starting motor is in contact with or grounded to the frame of the car.

Any wires having injured insulation should be wrapped with electrical tape to prevent metallic contact between the conductor and the frame.

Open circuits are best indicated by feeling of the wires where they fasten to the terminals to make sure that positive contact is made and that the terminal binding nuts are not loose.

Short-circuits may also be located if no test lamp is available by following the various wires, and if any of these are found in contact with the frame, it is a wise precaution to pull them away and to wrap the section that was in contact with the frame thoroughly with insulating tape.

If one lamp flickers and the rest burn brightly, look for a poor connection between the lamp and the lamp connector, a loose terminal at the junction switch or a defective fuse.

If all lamps flicker, look for loose connections in wiring between battery and junction switch. When lamp bulbs have been renewed in headlights it is sometimes necessary to refocus the lamps.

Headlights should not exceed 15 candle-power, and should always be of the high efficiency filament type. Cheap carbon filament lamps will not only consume undue current but will not prove enduring. Tungsten filament lamps are best.

Cleaning Lamps.—To clean head and side lamp reflectors, remove from lamp body and carefully blow out any dust which may have collected on the reflecting surfaces. Then dip a small piece of absorbent cotton in alcohol and lightly wipe over the surface—always from the back to the front.

FOCUSING LAMPS

To focus the lamps, open the swinging front of the lamp and direct the light upon some smooth vertical surface at a distance of about ten feet. Loosen the adjusting screw on the slide at the rear of the reflector, and move the bulb and socket out and in until all rings disappear in the illuminated area. Then tighten down the adjusting screw and close the lamp. Any further adjustment of the lamp must be made by bending the arms of the lamp bracket with a heavy wrench until the light from each lamp strikes the road at the point desired.

STARTING SYSTEM HINTS

Do not connect additional apparatus, such as electrical horns, cigar lighters, etc., to the system without taking the matter up with the factory. The surplus capacity of the system is large, but there is a limit to the amount of current which the generator can produce.

Use the same judgment and reason in the operation of the electric lights on a car as you do those in your home or garage. When a car is running it is not necessary to burn all the lights; the two heads and the tail are all that are required or that are of any service. When the car is standing at night, use the side or dimmer lights or pilot bulbs and tail lights only.

When push type connectors are used, if halves of connectors are loose when pushed together, the contact will be poor. Spread the connector posts slightly so that they will slide in their sockets snugly. If Ediswan type are used, and plunger springs in connector do not operate, replace the connector with a perfect one.

If a metal battery box is used it must be thoroughly wiped out with a cloth saturated with ammonia to neutralize the acid and prevent corrosion. The top of the battery must be kept clean and dry to prevent a leakage of current between the terminals. See that the battery is held securely in its box or other container and that clamping bolts are tight. If necessary, pack tightly with waste to prevent the battery shaking about from jolting of the car.

Tools, other metal articles, or anything of value should not be placed near the battery, as the acid fumes will corrode and destroy metal, cloth and like material.

Make certain that the battery terminals cannot touch the cover of a metal battery box. A thin sheet of wood fiber fitted inside the cover of the battery box will prevent short circuits or grounds from this cause.

It must be remembered that the efficiency of any storage battery decreases with drop in temperature and it is only about 50 per cent efficient at zero temperature. For this reason the demand for current should be kept as low as possible in cold weather and lamps turned off when not needed.

Starting System Don'ts.—Don't replace worn-out brushes with any others than those supplied by the manufacturer.

Don't put oil or grease on the commutator of the generator or motor. No lubrication is wanted there.

Don't turn the hose on the generator or motor when washing your car.

Don't tighten up on the silent chain drive unless the slack becomes excessive from stretching. The chain must be run with a reasonable amount of slack to prevent noise and wear.

Don't fail to lubricate the silent chain drive at frequent intervals. Noise will be eliminated and wear reduced. Keep the chain and sprockets clean, and free from dirt and gravel.

Don't run your car, if for any reason the battery is disconnected from the circuit, unless you have disconnected the chain driving the generator, or the generator itself has been removed.

Don't attempt to propel car with starter. Such "stunts" are interesting, but expensive. Gasoline is for that purpose.

Don't attempt to make adjustments of any kind in the circuit breaker.

Don't fuss with the system when it is operating properly.

Don't remove any electrical apparatus from the car or make any adjustments without first disconnecting the storage battery. This can be done most conveniently by removing the ground connection. Remember, a loose, corroded or dirty connection on the battery can put both starting and lighting systems out of commission.

Don't fail to immediately switch off the offending circuit if the automatic circuit breaker of a Delco system buzzes and indicates a short circuit.

The Care of the Storage Battery.—The storage battery is the part of the lighting and starting system that requires the most attention, and unless this receives periodical inspection it is apt to be seriously damaged. The interior construction of an Exide double seal, burned connector type cell is shown at Fig. 412. The first point to observe is cleanliness of the battery and interior of the battery compartment, which must always be clean and dry. All small articles, especially of metal, must be kept away from the battery. All terminals and connections should be kept coated with vaseline. If any electrolyte has spilled out of the battery, it should be wiped off with waste wet with ammonia and the bottom of the battery compartment covered with a small amount of slaked lime to neutralize the acid. It is essential that pure water be added to all cells regularly and at sufficiently frequent intervals to maintain the solution at the proper height above the plates. This height varies in different batteries, but the important point to observe is that the plates are always covered with solution. The solution should never get below the top of the plates.

The vent plugs are removed to add the distilled water, which may be introduced with a syringe, and should always be screwed down tight after filling. In warm weather the battery cells should receive distilled water every week, and once every two weeks in cold weather. Never add acid to the solution and do not use any water known to contain even small quantities of salts or mineral water of any kind. If distilled water is not available, melted artificial ice or fresh, clean rain water may be used. The water should be added at regular intervals, as recommended, even though the battery may apparently function correctly without it.

The best way to determine the condition of the battery is to test the specific gravity of the solution in each cell with a hydrometer. A convenient time to do this is when water is added, but the reading should always be taken before any water is introduced into the cells. Specific gravity readings are made with a hydrometer syringe of the type shown. To take a reading with this instrument, insert the end of the rubber tube in the cell, being sure to place it below the level of the electrolyte. Squeeze the bulb, then slowly release it to draw up enough electrolyte from the cell to float the hydrometer. The reading is taken from the graduated stem of the hydrometer at the point where it emerges from the solution.

The gravity reading is expressed in "points," the difference between 1.275 and 1.300 being 25 points. After testing, the electrolyte must always be returned to cell from which it was taken. When all cells are in good order the gravity should test within 25 points of being the same in all cells. A reading above 1.200 indicates the battery is more than half charged. The nearly complete charge is indicated by a reading of about 1.275. A reading below 1.150 indicates that the battery is completely discharged. The complete charge is indicated by a reading anywhere between 1.275 and 1.300.

In charging from an outside source, which is often necessary if the car is operated extensively at night and very little in the daytime, or if the engine starts hard, there are two possible methods. Only direct current can be passed through the battery, although, of course, the current flowing through the mains may be either direct or alternating. The most convenient method of charging when a direct current is available is to use a lamp bank resistance as indicated in one of the accompanying sketches. This limits the current to the proper charging rate in amperes depending upon the number of lamps used. The ordinary six-volt battery will be properly charged if five 110-volt, 32-candlepower carbon filament lamps or ten 16-candlepower carbon filament lamps are used. It will take thirteen 40-watt tungsten lamps to accomplish the same results.

Always connect the positive terminal of the battery, which is that marked "P" or indicated with a plus sign, to the positive

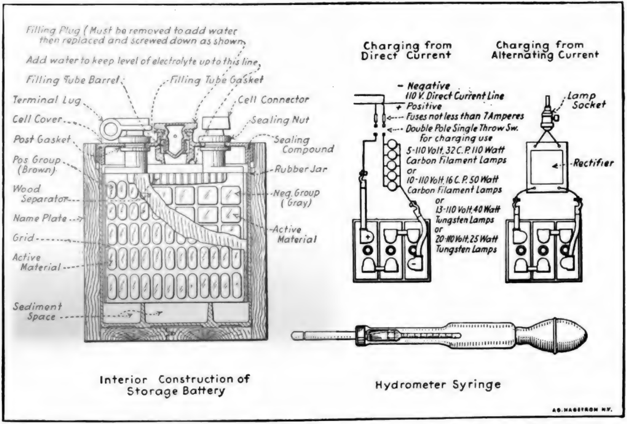

Filling Plug (Must be removed to add water then replaced and screwed down as shown
Add water to keep level of electrolyte up to this line
Filling Tube Barrel
Filling Tube Gasket
Terminal Lug
Cell Connector
Cell Cover
Sealing Nut
Post Gasket
Sealing Compound
Pos Group (Brown)
Rubber Jar
Wood Separator
Neg. Group (Gray)
Name Plate
Active Material
Grid
Active Material
Sediment Space
Interior Construction of Storage Battery
Charging from Direct Current
Charging from Alternating Current
− Negative
110 V. Direct Current Line
+ Positive
Fuses not less than 7 Amperes
Double Pole Single Throw Sw. for charging use
5-110 Volt, 32 C. P. 110 Watt Carbon Filament Lamps
or
10-110 Volt, 16 C. P. 50 Watt Carbon Filament Lamps
or
13-110 Volt, 40 Watt Tungsten Lamps
or
20-110 Volt, 25 Watt Tungsten Lamps
Lamp Socket
Rectifier
+
−
Hydrometer Syringe
AG. HAGSTROM N.Y.

Fig. 412.—Illustrations Showing Sectional View of Storage Battery and Methods of Charging from Direct and Alternating Current. Note also Hydrometer Syringe for Testing Specific Gravity of Electrolyte.

charging wire and the negative terminal of the negative charging wire. If connections are reversed, serious injury to the plates will result. The charging wires may be tested for positive or negative polarity by trial with a voltmeter or by dipping the ends in a glass of water containing a few drops of electrolyte. This will indicate the negative wire by the bubbles formed upon it.

Any storage battery which is to stand idle should first be fully charged. A battery not in active service may be kept in condition by giving a freshening charge at least once a month, but it should also be given a thorough charge before it is replaced in service. In order to avoid freezing the battery it should always be kept in a fully charged condition. A discharged battery will freeze at 20 degrees above zero, while one that is one-quarter discharged and which shows a specific gravity of 1.260 will not freeze at temperatures exceeding 60 degrees below zero.

When 5-32 candlepower lamps are used in the lamp bank it means that five amperes will flow through the battery. If the battery is completely discharged and it is a 100-ampere-hour type, it will take approximately 24 hours to charge it completely. When alternating current only is used for the lighting mains it is necessary to interpose a rectifier between the line wire and the storage battery. Simple rectifiers that may be connected to any lamp socket may be obtained at relatively small cost from dealers in electrical appliances. During the winter season it is well to remember that a storage battery is only about 50 per cent as efficient as during warm weather, and the lamps should only be used when necessary and no current wasted in useless engine starting. A depleted storage battery always shows when it is discharged by causing the lamps to burn dimly or supplying so little current that the starting motor will barely turn the engine crankshaft over.

Inspection and Care of the Dynamo and Motor.—The manufacturers of starting and lighting systems have made every effort to have the various units function as nearly automatically as possible. At the same time some attention will be needed by the other parts of the system, though these do not need the periodic inspection that must be given the storage battery. The dynamo should be looked over and any carbon dust that has been worn away from the brushes due to the abrading action of

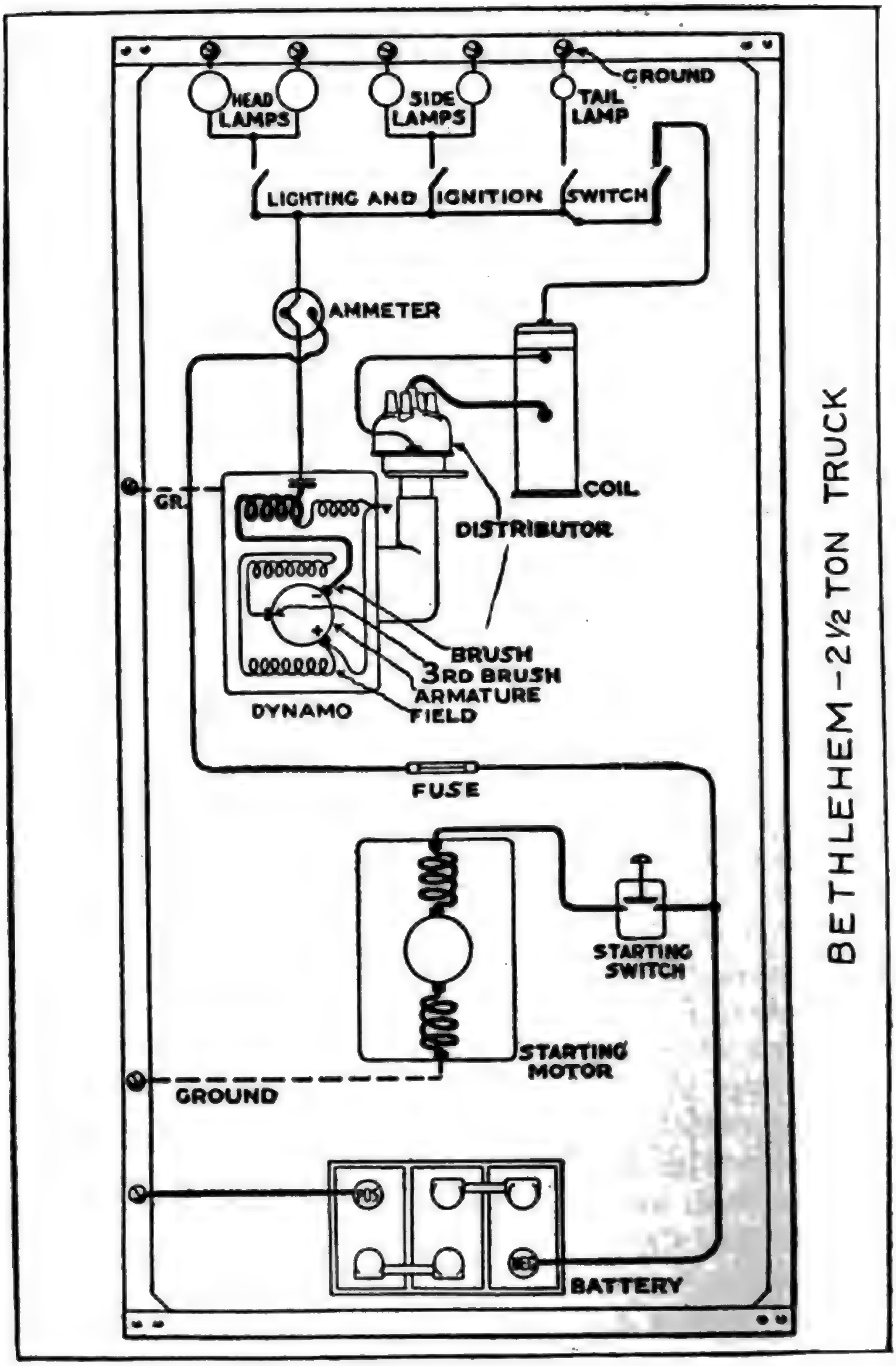

GROUND
HEAD LAMPS
SIDE LAMPS
TAIL LAMP
LIGHTING AND IGNITION SWITCH
AMMETER
COIL
DISTRIBUTOR
GR.
BRUSH
3RD BRUSH
ARMATURE
FIELD
DYNAMO
FUSE
STARTING SWITCH
STARTING MOTOR
GROUND
POS
NEG
BATTERY
BETHLEHEM - 2½ TON TRUCK

Fig. 413.—Electrical System of Bethlehem 2½-Ton Truck.

the commutator and which has fallen to the lower portion of the commutator compartment should be blown out with compressed air, because a considerable accumulation of this material, which is a conductor of electricity, may allow a leakage of current to the ground or produce a short circuit between the brush carrier and the generator casing. A blackened or rough commutator must be smoothed down with fine sandpaper while the armature is rotating. The makers give positive instructions that emery cloth should not be used for this purpose. After the commutator has been smoothed, all particles of metal should be removed from the insulation between the copper segments, and care should be taken that this insulating material does not project higher than the surfaces of the segments. Any projections should be filed down to a lower level than that of the copper members upon which the brushes bear.

The brushes must not only make perfect mechanical contact with the commutator, but they must also be in good electrical connection with it. Oil or grease on the brush assembly or segments should be removed, and it is well to make sure that there is sufficient spring tension to keep the brushes in positive contact with the commutator. At the same time, the spring tension should not be excessive, because too much spring pressure will cause untimely deterioration of the brushes and will also tend to heat the commutator. The starting motor is subject to the same electrical troubles as the generator. Defects in either the motor or dynamo driving mechanism are of a purely mechanical nature and can be easily corrected by any mechanic. The centrifugal governors used on a number of the generators applied to cars several years old are not apt to give trouble unless parts become broken or the action becomes clogged with gummed oil or grease. Any oil between the clutch faces will prevent proper frictional adhesion, while broken links or springs in the governor mechanism will disturb the continuity of the drive.

Lamp Troubles and Their Causes.—All wiring should be protected from the possibility of becoming covered with grease, oil or water, and in all cases the regular insulation should be supplemented by a conduit of insulating material or a substantial armor. All connections should be gone over to make sure that these are tight. If a fuse is blown or if the protective circuit breaker operates, this indicates a "short circuit" between one of the current-conveying wires and the metal frame of the car. A

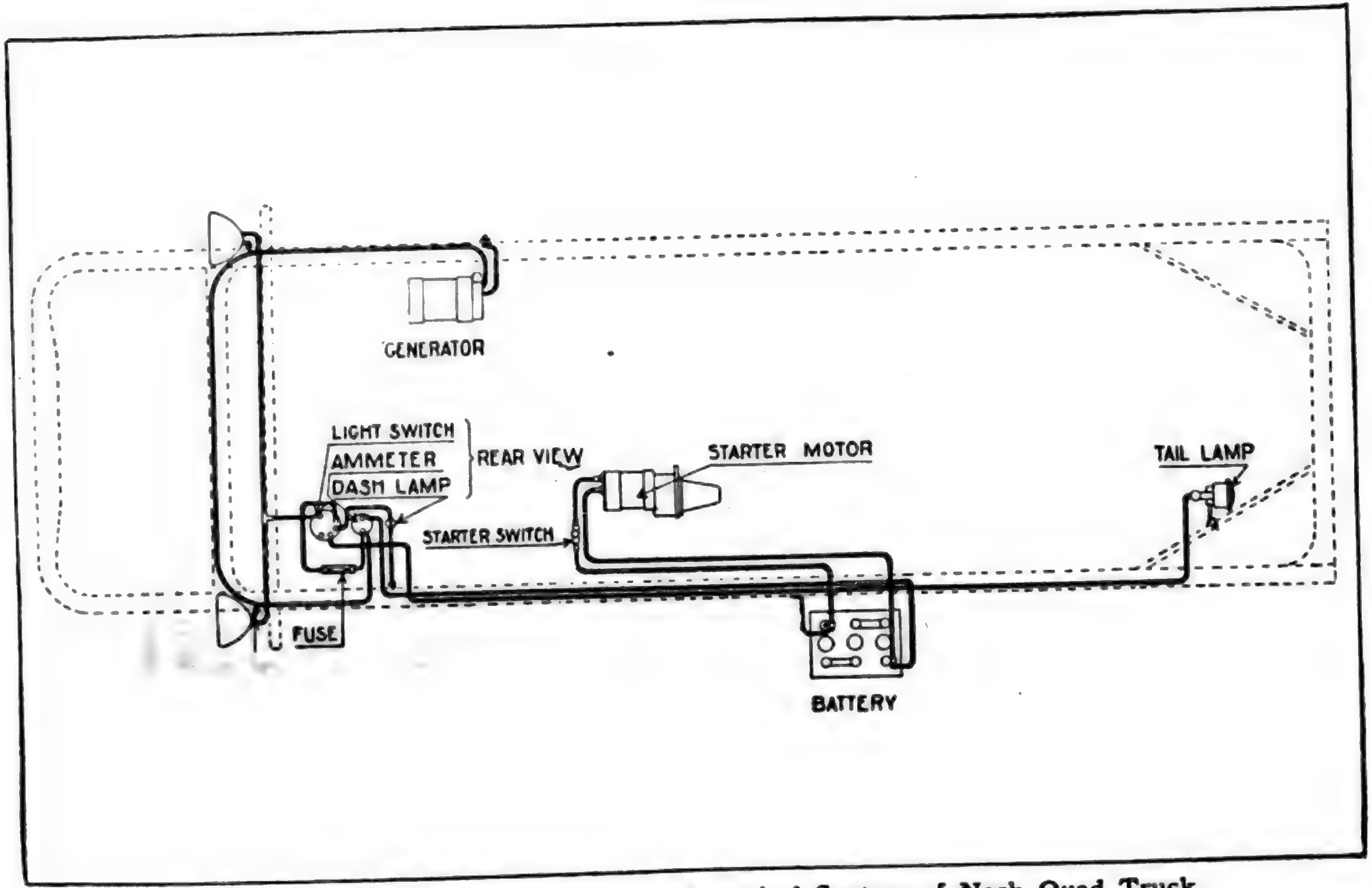

GENERATOR
LIGHT SWITCH
AMMETER
DASH LAMP
REAR VIEW
STARTER MOTOR
TAIL LAMP
STARTER SWITCH
FUSE
BATTERY

Fig. 414.—Wiring Diagram Showing Electrical System of Nash Quad Truck.

short circuit is often indicated by the action of the amperemeter. If the pointer vibrates on the discharge side it shows that there is a path for the passage of current between one of the wires leading to the lamps or other current-consuming units and the frame. If the lamps do not functionate properly, trouble may be looked for in the wiring or in defective lamps. In many lighting systems the dash and tail lights are wired in series, and if one of these goes out it will produce a break in the circuit and automatically make the other go out also. Lamp troubles may be usually laid to defective wiring, "grounds," loose contacts, defective fuses and switches. Dim lights indicate a rundown storage battery.

The user of an electric starting and lighting system will avoid trouble by observation of the few simple rules which follow and which have been formulated by a prominent manufacturer of these systems:

First—Always be sure that the battery is properly charged and that all connections throughout the system are clean and firm. Second—If the generator is suspected, the only point liable to be at fault is the brush contact at the commutator or accumulations of oil and grease on the commutator. Short-circuited armature or field windings are extremely rare. Do not replace worn-out dynamo or starting-motor brushes with any other than those supplied by the manufacturer, and be sure that the brushes are properly fitted to the commutator. Never put oil or grease on the commutator of the generator or starting motor, as this is a point that requires no lubrication. Never turn the hose on the generator, starting motor or any of the regulating devices when washing the car. Third—Inspect the generator driving means from time to time. If a silent chain is used don't tighten up the chain unless the slack becomes excessive from wearing of the link rivets. It is necessary to operate a silent chain reasonably loose to prevent noise and wear. The silent chain drive, if exposed, must be cleaned at frequent intervals and lubricated. Fourth—Never run the car if for any reason the battery is disconnected, unless the chain driving the generator or the generator itself has been removed. Never attempt to propel a car with a starter. Such "stunts" are possible, but expensive! Do not attempt to make any adjustments of any kind in the circuit breaker, regulating relays or dynamo-output governors. Always have this work done by a competent mechanic familiar with the system. Never fuss with the system when it is operating properly.

Washing the Truck.—When the varnish is new and not very thoroughly seasoned it is easily affected. Washing frequently with pure water hardens the varnish and keeps it from spotting. Do not wash hood while it is hot. The effect is the same as washing it with hot water, the result being that the gloss disappears before long and the finish is very apt to crack.

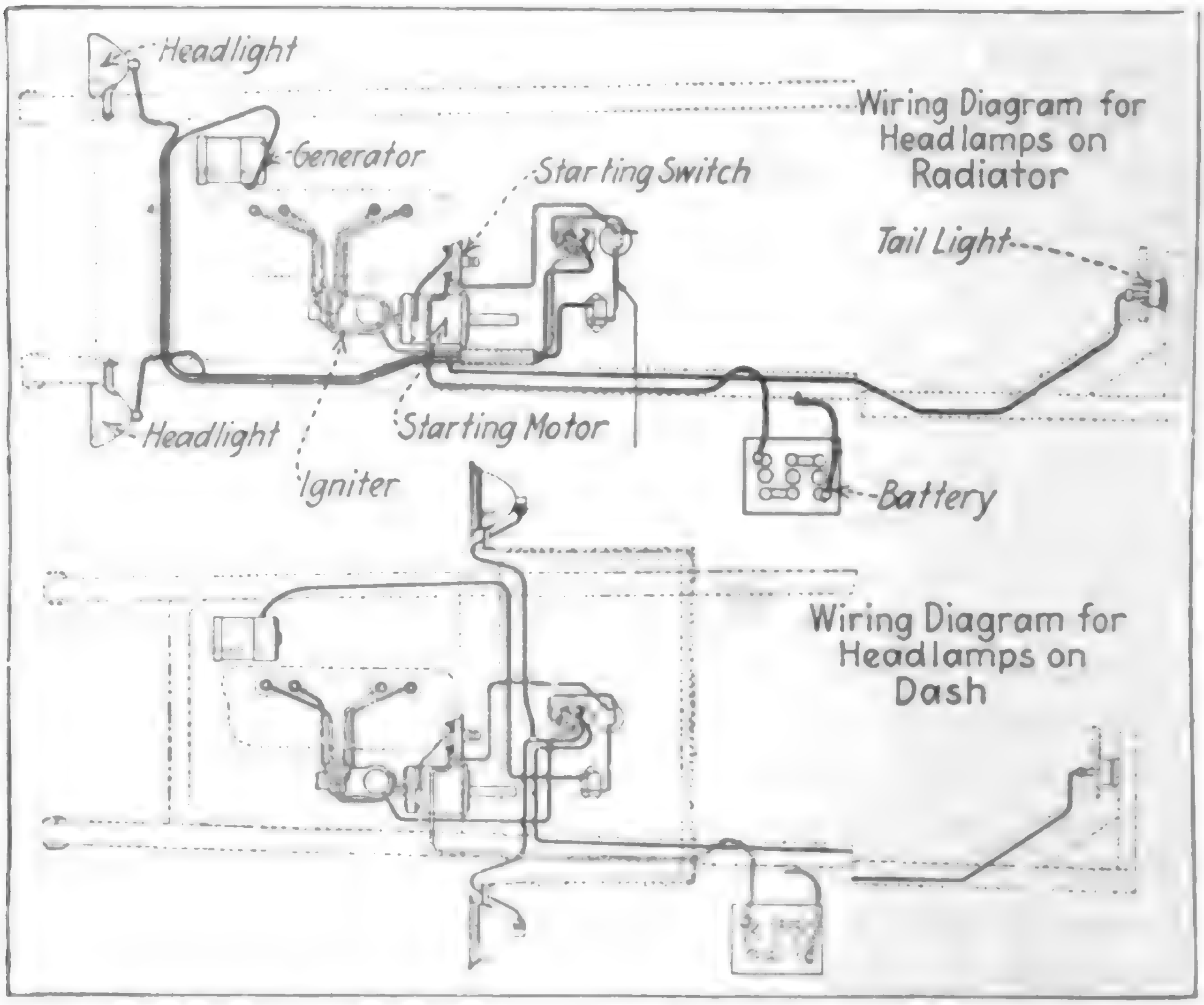

Headlight
Generator
Starting Switch
Wiring Diagram for Headlamps on Radiator
Tail Light
Headlight
Starting Motor
Igniter
Battery
Wiring Diagram for Headlamps on Dash

Fig. 415.—Wiring Diagrams Showing Electrical Systems of Nash Light Truck.

When washing a truck care should be taken that water in large quantities does not get inside of hood and accumulate in the valve caps and other places where it would be most undesirable. If water gets on hot spark plugs, cracking is sure to result. Special care should also be observed in connection with the clutch oil retaining rim of the flywheel, for it will serve equally well in retaining water, which will be damaging to the clutch leather. Do not allow water to get on the clutch or inside of the flywheel. Caution should be exercised to keep the dust pan as clean as possible. Accumulation of oil, grease, etc., constitutes a serious danger from fire that should not be overlooked. It is advisable to disconnect one of the battery terminals before cleaning engine with kerosene. Never use gasoline for cleaning.

Grit, mud and dirt are the sources of greatest wear to a motor truck. If all such deposits are promptly removed after every run, the life of the truck will be greatly prolonged.

Metal Polish.—For polishing metal parts, use any good polish and take care not to get any on varnished parts of the truck. After liquid polish has dried on metal parts, take a rag moistened with water, sprinkle on a few drops of alcohol and rub off dried polish. Then polish with dry rag. Use crude oil or kerosene and apply with a soft rag to remove road oil and hardened grease. Use clean vinegar and apply with a soft cloth (cheesecloth or gauze) to clean celluloid.

CHAPTER XII

GASOLINE TRUCK REPAIR AND ADJUSTMENT

Tools and Accessory Equipment of Trucks—Engine Repairing—Loss of Power—Poor Compression—Carbon Deposits—Valve Grinding—Timing Valves—Timing Gears—Timing by Piston Movement—Replacing Gasket—Care of Piston and Rings—Noisy Operation—Adjusting Bearings—Scraping Bearings—Mixture Troubles—Ignition System Derangements—Cooling and Lubrication—Group Faults—Clutch Repairs—Looking Over Gear Box—Transmission of I. H. C. Truck—Rear Axle and Shafts—How to Adjust Gears in the Timken-Detroit Rear Axle—I. H. C. Rear Axle—To Adjust Bevel Gears—Worm Drive Axle—Chain Drive—Care of Chains—Care of Brakes—Service Brake—Pierce Truck Brakes—Gear and Wheel Pullers—Wheel Alignment—Care and Adjustment of Front Wheel Bearings—Rear Wheel Bearings—Steering Gear, Care and Adjustment of—Chassis Repairs.

Tools and Accessory Equipment of Trucks.—The following is supplied as standard equipment on all Pierce-Arrow chassis: Cab Top, Cushion, Curtains, Frame, Sills and painting to specifications: Hubodometer, Hand Klaxon Horn, two Side Lamps (oil), one Tail Lamp (oil), license number attaching plates.

A Heavy Reinforced Tool Box is mounted on rigid brackets. This is shown at Fig. 416, attached to the chassis frame and located on right-hand side of truck. Tool box has armored top and Yale lock with duplicate keys. The interior is arranged with compartments and with straps to hold the contents firmly in place. A special place is provided for clamping on the vise when it is being used on the road.

The Tool Box Contains

1 5-lb. Can Gear Grease
1 1-lb. Can special Lubricating Compound for Water Pump
1 1-gal. Can Engine Lubricating Oil
1 Neatsfoot Oil Can.
1 Machine Oil Can
1 8-inch Flat Mill File
1 6-inch Round Bastard File
1 Funnel

1 Hammer
1 Jack
1 Rubber Pail
1 8-inch Reed Pliers
1 Grease Pump
1 Nail Set
1 8-inch Perfect Handle Screwdriver
1 2-inch Perfect Handle Screwdriver
1 Wrench for Carburetor Adjusting Needle
1 6-inch B. & S. Wrench
1 7-inch B. & S. Wrench
1 14-inch B. & S. Wrench
1 No. 723 Open End Wrench
1 No. 27 Open End Wrench
1 Hub Cap Wrench
1 Magneto Wrench
1 Fan Belt
2 Mounted Valves
2 Spark Plugs
1 Vise
Cotter and Taper Pins
1 No. 23292 Open End Double Head Wrench
1 No. 1034 Open End Double Head Wrench
1 No. 36819 Open End Double Head Wrench for Spring Clips.
1 No. 20361 Valve Cap Wrench and Handle

Another typical outfit of tools supplied with high-grade trucks is shown at Fig. 417, this being the equipment furnished with

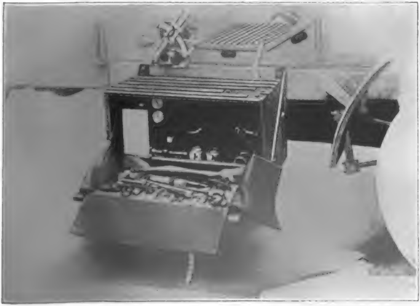


Fig. 416.—Tool Outfit of Pierce-Arrow Truck, and Method of Carrying This Equipment.

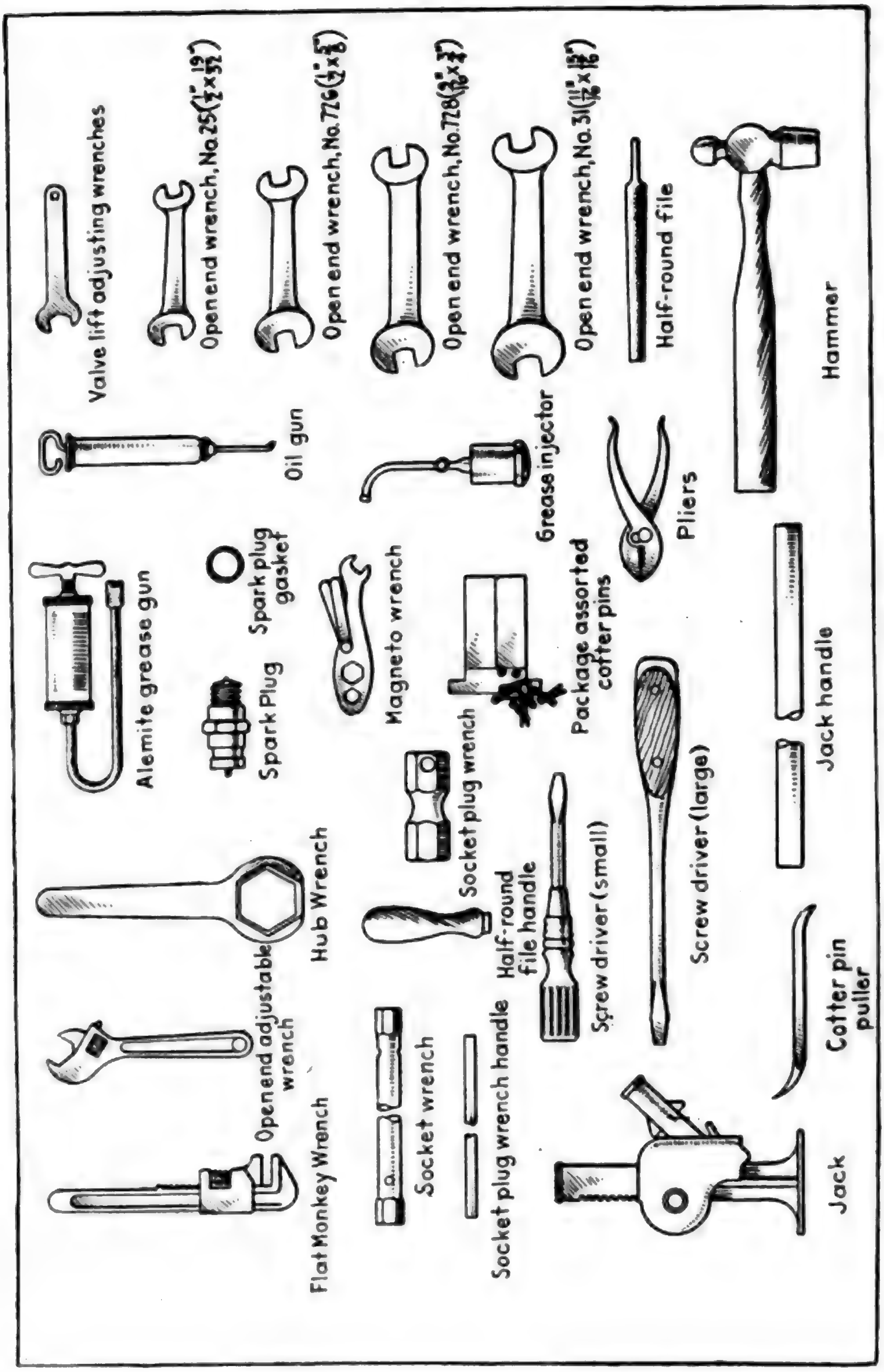

Valve lift adjusting wrenches
Openend wrench, No. 25 ($\frac{1}{2}$" x $\frac{19}{32}$")
Open end wrench, No. 726 ($\frac{1}{2}$" x $\frac{5}{8}$")
Open end wrench, No. 728 ($\frac{9}{16}$" x $\frac{3}{4}$")
Open end wrench, No. 31 ($\frac{11}{16}$" x $\frac{13}{16}$")
Half-round file
Hammer
Oil gun
Grease injector
Pliers
Alemite grease gun
Spark plug gasket
Spark Plug
Magneto wrench
Package assorted cotter pins
Socket plug wrench
Jack handle
Hub Wrench
Half-round file handle
Screw driver (small)
Screw driver (large)
Openend adjustable wrench
Flat Monkey Wrench
Socket wrench
Socket plug wrench handle
Cotter pin puller
Jack

Fig. 417.—Tool Outfit Supplied with White Trucks.

White trucks. As all parts are clearly indicated in the illustration, it is not necessary to enumerate the various items. Enough tools are supplied to do ordinary repairs and make usual adjustments, but for a complete overhauling a number of special tools will be required.

Engine Repairing.—The main troubles with the power plant are loss of power, irregular action, overheating, and noisy operation. The first usually denotes some fault in the piston rings or valves of the engine, and is due primarily to poor compression. Irregular operation, which is the condition that exists when cylinders do not fire regularly, is nearly always the result of defects in the gas supply system or the ignition appliances. Overheating invariably denotes inadequate lubrication or failure of the cooling system. Noisy operation can always be accepted as a condition due to mechanical wear.

Loss of Power.—While loss of power is usually a condition that can be ascribed to poor compression, it will result indirectly if any of the other faults are evident. Obviously, if an engine is missing explosions and is not firing regularly, its power will be reduced materially and thus the condition of "skipping" or "missing fire," as it is called, will produce loss of power indirectly. If the engine is overheated so that the various parts are running with considerable friction, there will be a loss of power because of the increased internal load in the motor itself. Overheating may be directly caused by failure of the oil supply, in which case the consequences are apt to be serious unless the motor is stopped as soon as this defect is apparent. Troubles with the cooling system are easily determined by the steam which issues from the radiator or cooling tank. Motor truck power plants are generally housed in an accessible manner, as they are under a hood or bonnet and may be easily reached. The power plant shown at Fig. 418 is a typical truck engine, and some of the parts that may give trouble are shown in detail.

If it is desired to remove the cylinders, the first step is to take off the exhaust and intake manifolds, then the cylinder pairs or block may be pulled off of the engine base by removing the nuts that hold it in place. The valves may be ground without removing the cylinders, and, in fact, all working parts of this motor may be reached without taking the lower portions of the crankcase or engine bed from its position on the truck frame. If adjustments are necessary to the bearings of the crankshaft,

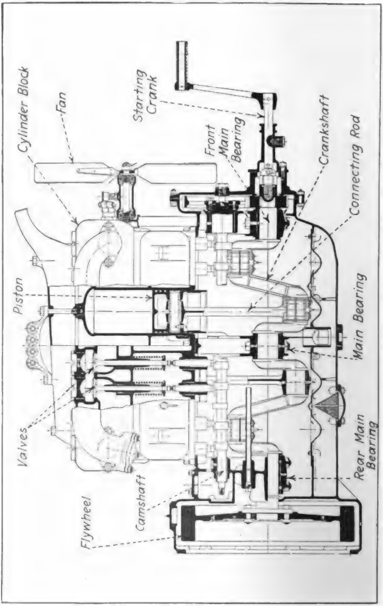

Cylinder Block
Fan
Starting Crank
Front Main Bearing
Crankshaft
Connecting Rod
Piston
Main Bearing
Valves
Rear Main Bearing
Camshaft
Flywheel

Fig. 418.—Typical Motor Truck Engine Showing Important Parts.

the bottom half of the horizontally divided crankcase may be removed without difficulty by loosening a few oil pipes and bolts holding the crankcase halves together. When this bottom member is removed the entire interior of the crankcase, including the camshaft, is open for inspection.

The point of accessibility is one that is given special prominence in the design of motor truck power plants; much more so than is the case in the small gas engines used for automobile propulsion. This is on account of the larger size of the engine parts and the difficulty which obtains in handling them without proper facilities.

A breakdown on the road is not always serious if the parts can be readily reached, but, on the other hand, it may mean the expenditure of considerable time and money if the entire engine has to be dismantled every time the interior mechanism is out of order. There are some automobile engines where it is practically impossible to reach the pistons without taking the cylinders off the engine bed and where the entire engine must be taken apart to get at the main bearings of the crankshaft or the bushings in the big ends of the connecting rods. This is not tolerated by the expert motor truck operator, and the factor of accessibility of components alone may make or prevent the sale of a machine.

Poor Compression.—If the engine is losing power and the power loss is not accompanied by skipping, overheating or noisy operation, it is due to poor compression. This results from conditions inside or outside of the cylinders that will allow leakage of gas from the interior. Gas may escape through defective valve operation caused by the valves not seating properly or being out of time. If the valve system is all right, the trouble is generally due to faulty piston rings or worn or scored cylinders. The method of testing for poor compression is simple, consisting of cranking the engine without the ignition system being turned on and with compression relief cocks closed. If the engine turns over easily and no appreciable resistance is felt, it is invariably due to a loss of gas from one or more of the cylinders. If it is a multiple cylinder engine, the defective member may be easily determined by cranking over the motor with all of the compression cocks, except one, open. Each cylinder is tested in turn, and the thing to remember is to keep the compression cock in the cylinder that is to be tested closed, while the others are left open so that the engine can be turned with minimum resistance. The cylinders that have good compression will offer a decided resistance to turning the crankshaft, while those in which compression is weak will permit one to turn the crank very easily.

If compression is poor, the first thing to do is to inspect the external parts which may be easily reached. This means looking for a leak at valve chamber caps, spark plug gaskets, or blown packing between cylinder and cylinder head, if that construction is employed. Other causes are broken valve springs, sticking or bent valve stems, poor valve plunger adjustment (usually caused by loose adjusting screw which has worked up and kept the valve from seating), or a defective priming cock. Some of the defects of the internal parts which may be looked for are a broken valve (rare), a warped valve head, dirt under valve head, which prevents valve from seating; burnt or pitted valve seat or valve head, cracked piston head or cylinder (rarely occurs), broken piston rings, piston ring slots in line, loss of

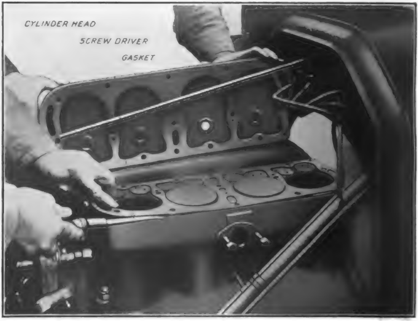


Fig. 419.—Showing Method of Removing Copper Asbestos Gasket Used Between Cylinder Head and Cylinder Block Casting of the Ford Engine.

piston ring elasticity or spring or piston rings gummed in the piston grooves. The piston and cylinder walls may be badly scored by defective lubrication or a deep groove may have been cut in the cylinder by a loose wristpin, which allows the gas to blow by very easily.

Carbon Deposits.—One of the fertile causes of general motor inefficiency and the one which most often contributes to loss of power, as well as noisy operation, is the deposit of carbon that accumulates in the combustion chamber. These deposits result from burnt cylinder oil and sometimes from excessively rich mixture, and are more apt to exist on motors operating on low grade fuel, such as kerosene or distillate, than in gasoline engines, where combustion is more perfect. These deposits accumulate on the piston top and in the interior of the combustion head and valve chamber. They interfere with correct valve operation by gumming up the valves and prevent a full charge from reaching the motor, as well as retarding the prompt expulsion of burnt gases by building up around the valves.

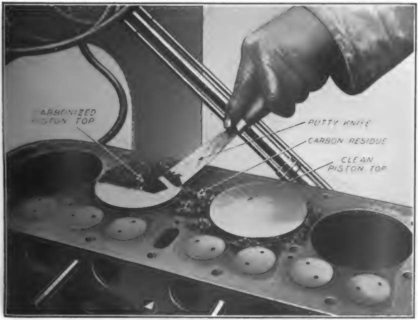


Fig. 420.—Method of Removing Carbon Deposits from Piston Top and Cylinder Block.

The deposits in the cylinder head may cause trouble, owing to some projecting particle remaining incandescent from the heat of a previous explosion and firing the fresh charge prematurely. Carbon deposits always produce loss of power, but their presence is usually clearly indicated by a pronounced knocking or pounding noise. The only remedy for this defective condition is to remove them from the engine interior. This is done by scraping away the material with small hoe-form steel scrapers that may be inserted through the holes left when the valve chamber caps are removed or by removing the cylinder head if the construction permits, as shown at Fig. 419. This is one of the marked advantages of the detachable head design. The head may be removed without disturbing the rest of the motor and the deposits of carbonaceous substance may be scraped from both cylinder head and piston, as at Fig. 420. If the deposits are of long standing and the motor is not a detachable head form it will be necessary to dismantle the motor in order to reach them and secure their positive removal.

This accumulation may be prevented by careful supervision of the amount of oil supplied the motor, making sure that it is never in excess of the actual requirements, using only the best grades of cylinder oil having a high fire test, and by careful regulation of the mixture to insure that the fuel and air proportions will be those that will burn without leaving a residue.

These deposits may be reduced to some extent by injecting three or four tablespoonfuls of kerosene into the cylinders at the end of a day's run, through the priming cocks. This softens the deposit which has accumulated during the day, and when the engine is started up the next morning the dissolved carbon will be ejected through the exhaust, as it will be carried out by the burnt gases. The soft deposit is not difficult to cope with and, in fact, various chemical carbon removers are advertised quite extensively which will remove it without making it necessary to take the motor apart, and it may be burned out with the aid of oxygen, provided the accumulations are not of too long standing. The hard, thoroughly baked on carbon can only be removed positively by mechanical means, as the repairman can be sure the troublesome deposit is removed when the parts are exposed as at Fig. 420.

Valve Grinding.—The most common cause of lost compression is leaky valves, and this condition materializes on even the best constructed motor truck engine. This is one point that requires periodical attention, and, as a rule, the first thing done, if the engine lacks power, is to grind in the valves to a new seating. The inlet valves do not need grinding as often as the exhausts do, but they are generally refitted at the same time that the exhaust members are ground to a new seat. When a valve needs grinding the defective conditions that make this necessary are apparent at a glance.

The first step when valves are suspected is to remove them from the cylinder. The method of doing this is clearly outlined at Figs. 421 and 422. It is necessary to release the valve spring pressure sufficiently so the key or pin which keeps the collar against the lower end of the valve spring in place may be withdrawn from the valve stem. The method of doing this is shown at Fig. 422. The first operation is to remove the valve cap and then the manifolds may be taken from the motor if it is not a detachable head type. If it is a detachable head type, as when the motor is an overhead type or one of recent design, it is not difficult to secure access to the valves by removing the head casting. The valve head is then kept in place by pressing down

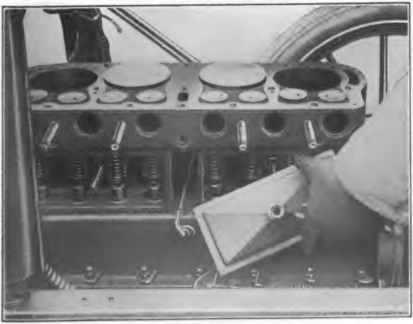


Fig. 421.—Valve Chamber Cover Plates Must Be Removed to Gain Access to the Valve Springs.

on it with a screwdriver and the valve spring is raised either by means of a special valve spring lifter or by using an end or S. wrench or any other fork form tool that will raise the valve spring without touching the valve stem. After the pin or key is withdrawn from the valve stem, the valve may be easily lifted from the cylinder.

The method of valve grinding is simple, and two ways of accomplishing this are shown at Figs. 423, A, and 424, B. Before the valve is replaced in the cylinder the stem is thoroughly cleaned by means of emery cloth and all gummed oil is cleaned out of the valve stem guides. A light spring is placed between the valve head and the end of the valve stem guide in order to raise it from its seat when pressure on the grinding tool is relieved. Special and somewhat costly valve grinding tools have been devised and, while these members are thoroughly practical, a very efficient and satisfactory appliance, which is almost universally used, is the ordinary bit brace. A screwdriver bit is made to turn the valve, provided that the head is properly slotted to receive this form of tool. Sometimes the valve head is pro-

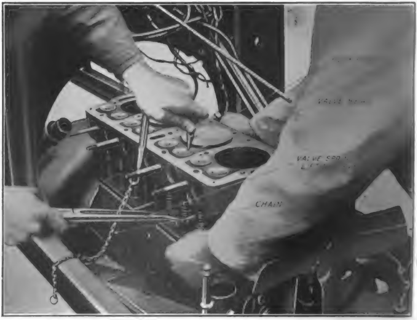


Fig. 422.—Special Tool for Raising Valve Springs When Inlet and Exhaust Manifolds are Taken Off of the Cylinder Block.

vided with two holes, and is then turned by a simple forked tool, which may be easily hammered up to shape so it will fit the bit stock.

The faces of the valve and the valve seat are smeared with a mixture of emery and oil made into a thick paste. If the valve surfaces are deeply scored or pitted it will be necessary to start grinding with a medium grade emery. In grinding, only sufficient pressure to keep the valve against the seat is used, and this is relieved from time to time in order that the valve may be lifted from its seat by the coil spring beneath it. Valves are not ground with a continuous rotary motion. The oscillating motion that would result if the bit stock was turned nearly a complete revolution and then back around again is better, lifting the valve from the seat frequently to prevent the accumulation of little balls of emery which may score the seat quite badly. Too much pressure will also do more harm than good. The valve should be taken from the cylinder and the

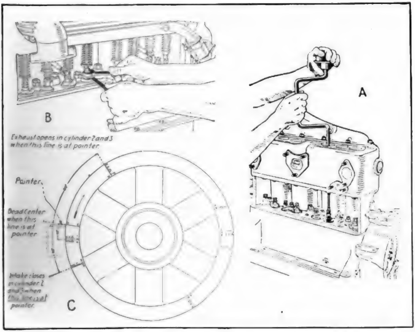

A
B
Exhaust opens in cylinder 2 and 3 when this line is at pointer
Pointer
Dead Center when this line is at pointer
Intake closes in cylinder 2 and 3 when this line is at pointer
C

Fig. 423.—Method of Grinding Valves in I. H. C. L Head Motor Shown at A. How to Adjust Tappets Shown at B. Valve Timing Marks for I. H. C. Engine at C.

valve head and seat thoroughly cleaned with gasoline. New abrasive should be used each time the valve is replaced for grinding. If the valve seat is very rough, the simple reaming operation shown at Fig. 425 will smooth it down and the grinding operation will not take as much time. It may be necessary to true off the valve face, also, if it is badly scored or pitted before grinding is attempted. This may be done with a simple hand tool made for the purpose or may be done by swinging the valve in a lathe and facing of the seat with a fine file if it is soft or with an emery center grinder if it is too hard to be filed.

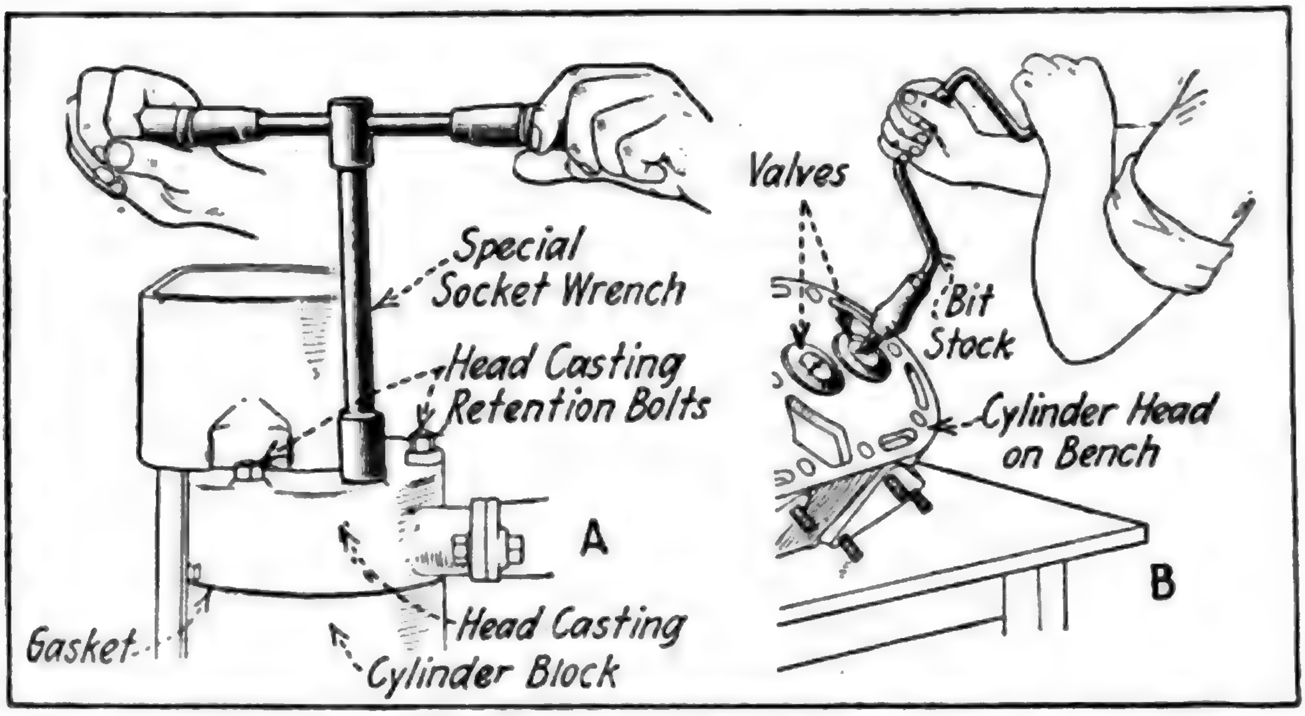


Fig. 424.—How to Remove Cylinder Head of Overhead Valve Engine at A. Method of Valve Grinding Clearly Outlined at B.

After most of the roughness has been smoothed down by grinding and the valve head and seat begin to have an even appearance, which is an indication of a smooth surface, the mixture of medium grade emery and oil may be replaced by one of floor emery, crocus, or ground glass, which may be mixed with kerosene, instead of the heavier lubricating oil. These make fine mixtures for polishing the valve seat. When the valve has been properly ground it will be smooth and have a bright ring all round its face. The valve seat will also show bright. An important precaution to observe when grinding valves, especially on horizontal motors, is that none of the abrasive reaches the interior of the engine cylinder. This is easily done by blocking the port or passage between the valve and combustion chamber with a wad of cloth, to which a string is attached so it may be withdrawn from the cylinder without trouble in case it should become dislodged from its position and fall in.

Timing Valves.—When the grinding process is completed and the valve springs have been replaced, it will be well to see that the valves are timed properly before the manifolds are put back. An important point to observe is that the proper amount of clearance between the end of the valve stem and the plunger is retained. During the process of grinding it may be possible to bed the valves down enough so that the stems will project farther down and bear against the valve plunger before the valve head seats in the valve chamber. After valves are ground it is good practice to go over the engine timing carefully and verify it. The flywheel of most truck engines of the multiple cylinder form is usually marked with letters which indicate the points where the valves open and close. The crankshaft should be turned by the starting crank, and when the point is in line with the trammel or indicator that usually indicates the vertical center line of the engine there should be no clearance between the

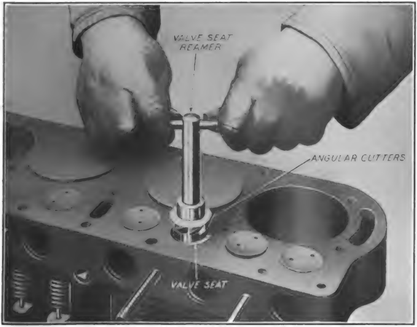


Fig. 425.—Showing Use of Valve Seat Reamer for Smoothing Scored or Pitted Valve Seats.

valve stem and the plunger that operates it. The method of adjusting the clearance on most truck engines is shown at Fig. 423, B, while typical markings are shown on the flywheel at Fig. 423, C, or Fig. 426, both of which are used on I. H. C. truck engines.

When the other valve is open in the same cylinder, then there should be an appreciable clearance between the valve plunger and end of valve stem. This is given as 0.007-inch for the inlet valves and 0.01-inch for the exhaust valves. More clearance is provided between the exhaust valve stems and plungers on account of the greater expansion of these members due to heat. If the engine timing has been disturbed, as is often the case when an engine is dismantled, care should be taken to replace the timing gears just as they were before the engine was taken

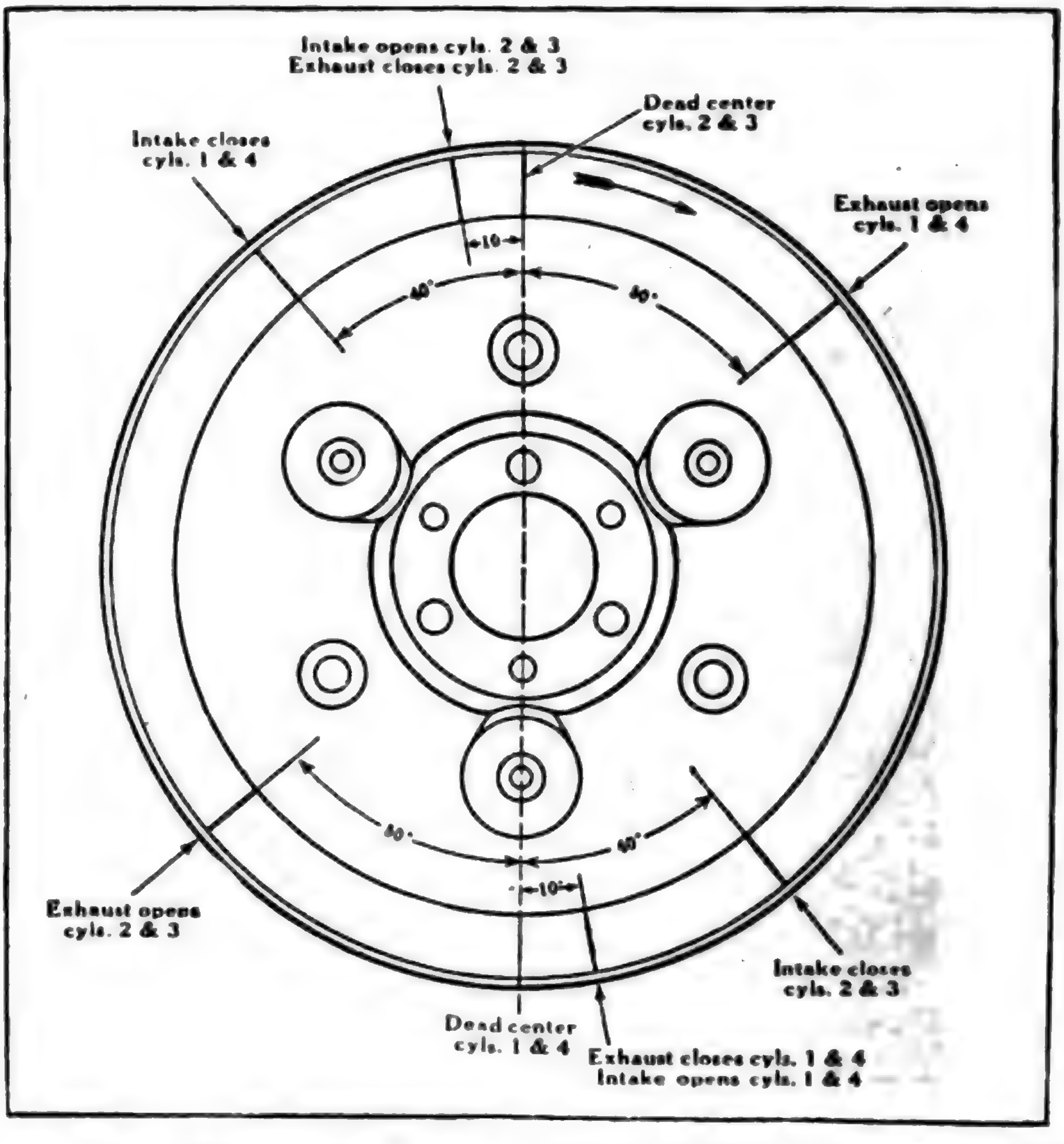

Intake opens cyls. 2 & 3
Exhaust closes cyls. 2 & 3
Dead center cyls. 2 & 3
Intake closes cyls. 1 & 4
Exhaust opens cyls. 1 & 4
10°
40°
40°
40°
40°
10°
Exhaust opens cyls. 2 & 3
Intake closes cyls. 2 & 3
Dead center cyls. 1 & 4
Exhaust closes cyls. 1 & 4
Intake opens cyls. 1 & 4

Fig. 426.—How Flywheel of I. H. C. Truck Engine is Marked to Facilitate Valve Timing.

apart. This is usually indicated by marks made by the manufacturer of the motor, as is clearly shown at Fig. 427. If no marks are noticed, then the repairman should be careful to make some for himself in order that he will be sure to replace the timing gears correctly. The best way to do this is to bring one of the pistons, preferably that in the front cylinder, to the top center and to see that both valves in that cylinder are closed. One tooth on the crankshaft gear is then marked with a center punch or steel letter stamp, or even with a cold chisel, if neither of the others is available. The teeth on the larger gear which drives the camshaft gear are then marked for future identification in the same manner.

In case the engine timing is lost and the gears or flywheel are not marked, approximate the proper timing as follows: The piston in either the front or rear cylinder is brought to the end of its upward stroke and the camshaft is rocked in such a manner that both valves are closed. The timing gears are then meshed and locked into place. The engine crankshaft is then turned about half a revolution and the exhaust valve is watched to see if it rises from its seat. If it rises from its seat when the piston is about three-quarters to seven-eighths of the way down on its stroke the engine may be considered timed approximately correct and if nothing else has been disturbed, such as the cams on the shaft, etc., the rest of the cylinders will undoubtedly be timed correctly enough so the engine will start without difficulty. If the exhaust valve opens late, the timing gear may be moved a few teeth and again meshed with the gear on the crankshaft. The crankshaft is rotated again and the opening of the exhaust valve again noted. The closing point is next determined by continuing to turn the crankshaft. The exhaust valve remains open during the next upstroke of the piston and does not close till after the piston starts on the intake stroke. Right after the exhaust valve closes, the intake valve should open and remain open during the next down stroke of the piston, at which time the cylinder should fill with gas. In some engines the inlet starts to open before the exhaust is fully closed.

To facilitate timing, it may be well to mark the flywheel at points to correspond to the position of the piston in the first cylinder when it is at the top of its stroke and similarly when it is at the bottom of the cylinder. These marks may be made with a center punch or steel stamp and should come directly

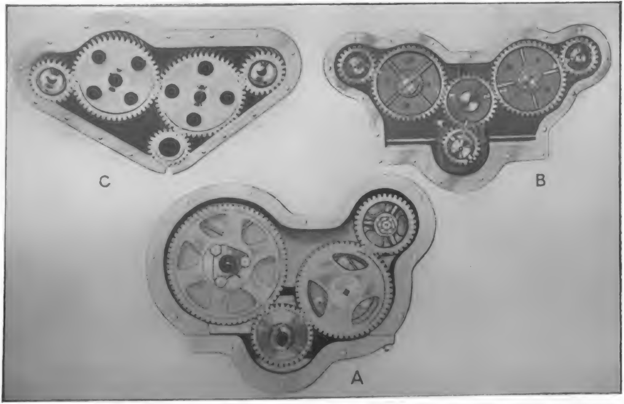


Fig. 427.—How Timing Gears of Garford Truck Engines are Marked to Insure Correct Meshing if Engine is Dismantled.

opposite each other. They are of greatest value on engines with enclosed crankcase, as when the crankshaft may be exposed by removing side plates, it is easy to follow piston movements by the position of the crankpin and connecting rod. The exhaust valve generally opens about 30 degrees crankpin travel ahead of the mark corresponding to the bottom position of the piston on the down stroke following ignition. The valve remains open the remainder of that stroke and the entire next stroke, closing a few degrees after the piston has started on the suction stroke.

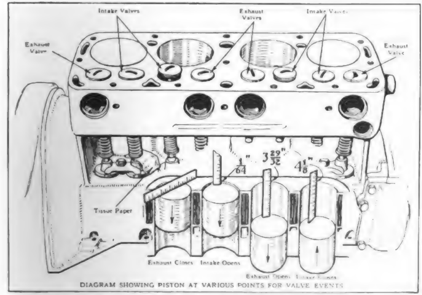
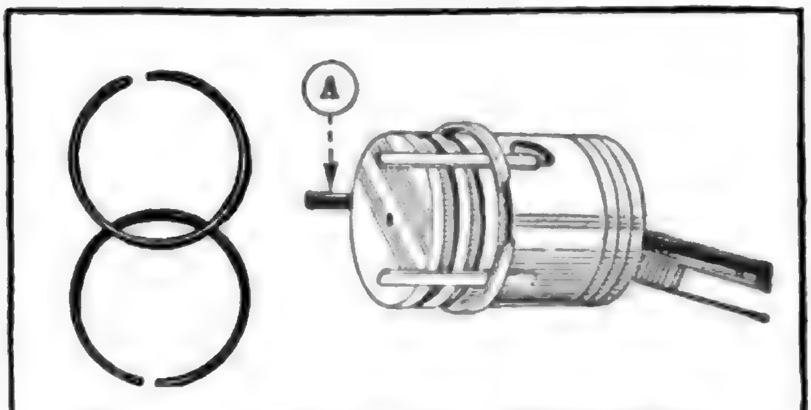

Intake Valves
Exhaust Valves
Intake Valves
Exhaust Valve
Exhaust Valve
$\frac{1}{64}$"
$3\frac{29}{32}$"
$4\frac{1}{8}$"
Tissue Paper
Exhaust Closes
Intake Opens
Exhaust Opens
Intake Closes
DIAGRAM SHOWING PISTON AT VARIOUS POINTS FOR VALVE EVENTS

Fig. 428.—How Valves of Dodge Bros. Motor are Timed.

The inlet valve opens about 15 degrees late and closed about 10 degrees late. The exhaust valve thus remains open a period equal to about 220 degrees crankshaft travel, the inlet valve seldom remaining open more than 180 degrees. The ignition spark, with timing lever at center position on quadrant, should take place just when the piston reaches the end of the compression stroke.

Timing Gears.—All gears are encased in an oil-tight compartment at the end of the crankcase. The removal of cover exposes all gears. The gears are lubricated by a constant supply of oil from pump. If any of the timing gears are removed, that is, the camshaft gear, the crankshaft gear, the idler gear, or the pump-drive gear, it will be necessary, when reassembling them, to be sure that the teeth are properly meshed in the same manner as before disassembling. If by chance the gears are removed without first ascertaining if they are properly marked, it will be necessary to retime.

If it is necessary to remove any of the timing gears and they are not punch marked, this should be done before removing to insure their replacement in identically the same position. The best method to follow is to put one punch mark on the crankshaft gear and one mark on the camshaft gear; two punch marks on the idler gear and the same on the corresponding bottom of the crankshaft gear; three punch marks on the pumpshaft gear and the same number on the corresponding bottom of the idler gear. Then, in replacing, these marks should all coincide to obviate the necessity of retiming from the marks on the flywheel. The markings of the timing gears on the Garford engines are shown at Fig. 427. That at A applies to Models 75C, 66B and 70B. The timing gear train at B is employed on Models 68 and 69. The gears at C are used on the motor of the Model 77B.



Removing and replacing piston rings.

Fig. 429.—Removing and Replacing Piston Rings with Steel Strips to Bridge the Grooves.

Timing By Piston Movement.—In the Dodge and Ford, or other removable head motors, the valves may be timed by following the piston movement with the cylinder head removed and measuring the distances as shown at Fig. 428, which outline completely the various dimensions used in timing the Dodge motor.

When the cylinder head and the cylinder head gasket are off and the valves are being ground at the monthly periodical inspection, the top of the piston should project 0.0312 ($1/32$) inch above the top face of the cylinder block. This particular piston would then be at its top dead center. Rotate the crankshaft, with a hand crank, in its normal direction or rotation until the piston head is flush with the top of the cylinder block. This may be ascertained by laying a steel scale or straight-edge across the two. At this point the exhaust valve should just have closed. Rotate the crankshaft in the same direction until the piston head is 0.015 ($\frac{1}{64}$) inch below this position, and the intake valve should just start to open. Rotate the crankshaft now until the piston goes to the bottom of its stroke and then starts up again. The stroke is 4.5 ($4\frac{1}{2}$) inches. When the piston has risen 0.343 ($\frac{11}{32}$) inch above the bottom center, the intake valve should just have closed. Measuring down from the top face of the cylinder block to the top of the cylinder head, the distance should be 4.125 ($4\frac{1}{8}$) inch when the intake valve has just closed. Continue rotating the crankshaft until the piston rises to the top of the stroke and again descends in order to determine the opening of the exhaust valve for that particular cylinder. The exhaust valve should just start to open when the piston has descended 3.906 ($3\frac{29}{32}$) inches, which is also 0.562 ($\frac{9}{16}$) inch above the bottom dead center position of the piston. This method of timing can be used with any detachable head motor, though the dimensions will vary with each make and should be secured from the truck maker or service station to be sure they are correct.

Replacing Gasket.—Before putting on new gaskets, the surfaces for the joint must be thoroughly cleaned. When tightening up a joint after a new gasket has been inserted, screw up all nuts fairly snug, then tighten uniformly, giving each nut a small part of a turn at a time. Continue this until all nuts are tight. Do not screw one nut down perfectly tight, and then go to the next, as you will not secure an even pressure on the gasket in this manner. After motor has been running a few minutes, tighten the nuts again. This operation may be greatly facilitated if a special socket wrench is employed, as shown at Fig. 424, A, which gives ample leverage to insure that nuts will be tightly drawn down. Care should be taken not to exert too much pressure, which might twist the studs off in the cylinder block.

Care of Piston and Rings.—Very often poor compression is caused by a defective condition of the piston or piston rings. If lubrication has been neglected and the cylinder has seized at any time, both the piston and cylinder walls will be found scratched and scored. Even if lubrication has not been neglected, but poor oil or an insufficient quantity has been used, the same scratches will be apparent though not to so large a degree. The piston rings may break, which will allow the gas to escape through the division between the broken parts. They may become gummed in their grooves so they do not spring out as they should and gas can blow by them. In cases where the piston rings are not pinned the slots in the rings may work in line and permit gas to escape through the series of openings. Piston rings often lose their elasticity or spring, or they may wear to such an extent that they will not form an effective seal against the explosive pressure. In the event of deterioration, the only method is to replace the rings with new members. If the piston rings do not work freely in the grooves, they should be removed from the piston and all burnt oil cleaned off. The carbon deposits which have collected in the grooves should also be removed before the rings are replaced.

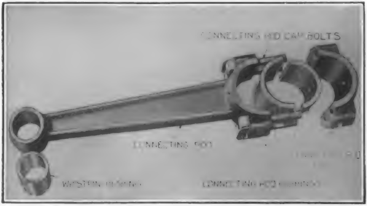


Fig. 430.—Connecting Rod of Typical Power Plant Showing Removable Crankpin Brasses.

When replacing the rings, put the center ones in first, using the metal strips as outlined at Fig. 429, A, so as to slide the ring over the groove. After the rings are in position, wash piston in gasoline to remove all dirt and grit. Then oil the piston and rings thoroughly and place the piston in the cylinder. Be sure that the rings are down in their grooves, then push piston into cylinder. See that oil hole in crankpin is open; this takes care of connecting rod bearings at this point, and it is essential that there be no obstruction to the free passage of oil. Now oil the crankpin, connect up, be sure that all liners are replaced, draw nuts tight, replace cotter pins and spread them at the ends.

The wristpin is secured by a dowel-pointed screw, the end of which projects through into the central hole and is drilled to receive a wire. As an additional safeguard against unscrewing, lock washers are used under the screw heads. In case it should ever be necessary to remove the wristpin, care must be taken in replacing it to see that the screws are set up tightly on the lock washers and the wire passed through the ends and carefully bent over to insure against coming out. Whenever the piston is accessible for examination these screws should be thoroughly examined and the engine should not be run unless they are tight and the locking devices secure.

BEFORE REPLACING CYLINDER HEAD, BE SURE THAT THE COPPER ASBESTOS GASKET IS PERFECTLY CLEAN AND IN GOOD CONDITION.

If the piston and cylinder walls are badly scored the only remedy is to have the cylinder bore ground out to a new surface and use a new piston member made to fit the enlarged bore. This will mean that new rings must be fitted as well as a new piston. Many believe that the cheapest way in the end is to secure an entirely new piston and cylinder from the makers to replace the defective members.

Noisy Operation.—A number of power plant derangements are readily noted because they give positive indication of trouble by noises easily distinguishable by the untrained ear. Knocking or rattling sounds are usually the result of wear in the connecting rods or main bearings, though often a very sharp knock, such as might be attributed to a loose bearing, is due to carbon deposits in the cylinder or combustion chamber, premature ignition due to advance spark lever, or a loose flywheel. Dry bearings are invariably indicated by squeaking sounds, and whenever this signal of distress is heard the engine should be stopped immediately and oil applied to the parts which have indicated their dry condition.

Leaks produce whistling or blowing sounds; a sharp, definite pitched whistle denotes the escape of gas under pressure and is usually produced by a defective packing or gasket that is used between the cylinder and cylinder head or as a joint for the exhaust manifold. A blowing sound is caused by leaky packing in the crankcase, worn main bearings or wearing the valve plunger guides. Grinding noises in the motor are usually caused by the timing gears and will be heard if these gears are dry or if they

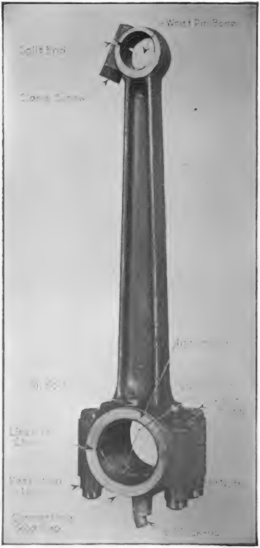


Fig. 430A.—Typical Connecting Rod Assembly, Showing Clamp Type Wristpin End.

have become worn. Minor rattles often indicate nothing more serious than too great clearance between valve stem and their operating plungers, or wear in the valve plunger guides. Any loose driving connection anywhere on the engine will contribute its quota of noise and often a combination of sounds are produced that will be very annoying even if they do not indicate serious wear.

Adjusting Bearings.—The most fertile source of noisy operation is wear in the main bearings of the engine or looseness in the connecting rod bearings. The points where deterioration produces the most noise are clearly indicated at Fig. 418, which shows the sectional view of a four-cylinder engine. This shows clearly the three main bearings of the crankshaft; two of these members, that on the rear and the one next to it, are cross hatched in order to show the shaft journals. Under the influence of the explosions the bearings in time tend to become hammered down a trifle and lost motion exists between the crankshaft and the bearing bushes.

If the wear is comparatively slight it may be eliminated by removing some of the thin shims of sheet metal placed between the bearing caps and the lower portion of the box and replacing the caps. A typical connecting rod assembly is shown at Fig. 430. This will enable them to bed down close to the crankshaft and the lost motion which produces the noise will not exist. If the bearings have worn to such an extent that removing the shims will not be sufficient, new brasses or bushings must be inserted in the boxes and scraped to fit the crankshaft. If the crankshaft is cut or scored the journals should be smoothed with fine emery cloth before attempt is made to fit the bearings to the shaft.

A conventional connecting rod in a disassembled condition is shown at Fig. 430, with the various parts separated in order that the construction may be clearly ascertained. It will be noticed that the small bushing which surrounds the wristpin is a solid member pressed into the boss at the upper end of the connecting rod. If any wear exists at this point the old bushing should be forced out and replaced by a new member. The lower portion of the connecting rod which encircles the crankpin is provided with a split box composed of two white metal bushings that bed into the connecting rod and the connecting rod cap, respectively. The two halves of the connecting rod lower end are usually separated by thin shims or liners, such as is used in main bearings, and if the connecting rod is not very loose lost motion may be eliminated by removing enough of thin shims and then joining the parts together securely. If the connecting rod big end brasses are worn too much to permit refitting, they can be easily replaced by new members secured from the maker.

The average motor truck operator is not apt to be a good enough mechanic to scrape in and refit a set of main bearings, but this process is not a difficult one to learn, the only requirements being that the workman shall be reasonably careful, have the proper tools and be patient enough to fit the bearings properly. The only special tools called for are a socket wrench to fit the bearing cap bolts and a set of scrapers, and will considerably facilitate refitting of bearings.

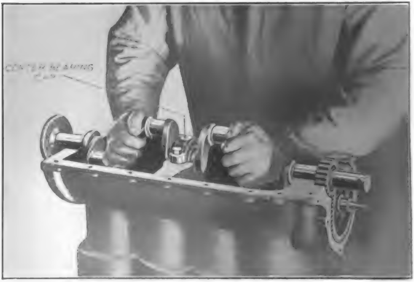


Fig. 431.—Showing Method of Testing Main Bearings when Refitting by Rocking the Crank Shaft by Hand.

Scraping Bearings.—A set of three scrapers will prove adequate for all sizes of bushings, while the socket wrench will make the constant removal and replacement of the bearing cap nuts a less difficult task than if the ordinary form of monkey wrench or spanner is used.

When refitting the main bearings, the first precaution should be to clean the crankshaft thoroughly. Only attempt to fit one box at a time; if more than one bearing cap is tightened it will be hard to tell which one is too tight. After the shaft and boxes have been cleaned, the main journals of the crankshaft should be coated with a very light, thin film of Prussian blue pigment, which may be obtained in a collapsible tube at any paint store. The crankshaft is then dropped in the boxes which are held by the engine base and revolved a number of times, as shown at Fig. 431, in order that all the high spots on the boxes will have a chance to run against the shaft. When the shaft is removed the high spots will be indicated by specks of blue on the brasses.

Before again replacing the crankshaft these high spots are scraped off by means of curved bearing scrapers, as outlined at Fig. 432. The shaft is again replaced and revolved so that it will indicate another set of high places. The scraping-in process is continued and the bearing points are evenly distributed at each box. The caps are the next to receive attention. The shaft is allowed to remain in place and one cap is fitted at a time. The crankshaft journals are kept covered with Prussian blue, a new film being put on with the finger each time a test for high places is to be made. The fitting is started with either the front or rear main bearing cap, which is brought against the shaft by means of the retaining nuts, until it is difficult to turn the shaft. The nuts are slacked up a trifle and the crankshaft turned. Part

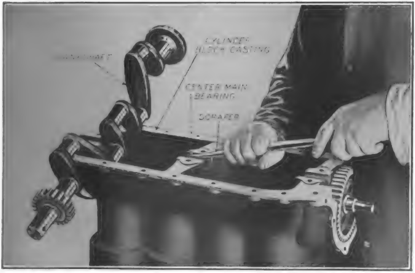


Fig. 432.—Showing Method of Scraping in Main Bearings to Fit Crankshaft Journals.

of the Prussian blue will be scraped off by the high points in the bearing caps and these are removed by the scraper and the fitting process continued until the bearing cap shows an equal bearing by a reasonably uniform distribution of color to all points.

The cap is properly fitted when the crankshaft does not turn unduly hard with the bearing cap retaining nuts bedded down firmly and the cap in firm contact with the engine base or the interposed shims of metal. Each cap is fitted in turn, and if the work is carefully done it will be found possible to turn the crankshaft over without much difficulty, when all the caps have been properly replaced, and no lost motion will exist between the caps and crankshaft.

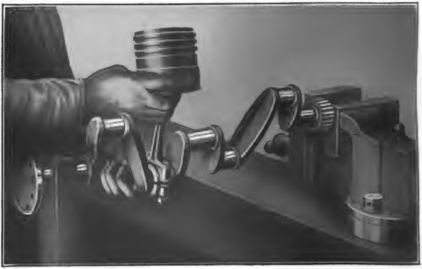


Fig. 433.—Connecting Rod Bearings May be Easily Fitted to the Crankshaft if This Member is Removed from the Engine and Supported by Bench Vise.

The same instructions apply to fitting connecting rods, the test for high spots being made by the use of Prussian blue pigment, and the trial to ascertain if the bearing clamps the shaft too tightly is made by rocking the connecting rods back and forth. The degree of resistance indicates the fit of the bearing. A connecting rod is usually considered properly fitted if it is not loose and yet will drop over slowly due to the piston weight when placed in a vertical position. Care should be taken not to adjust bearings too tightly, as this may produce sufficient heating to burn out the white metal bushings or score the crankshaft journals badly when harder materials, such as bronze, are used. Before replacing either connecting rod or main bearing caps for the last time, it will be well to use liberal quantities of cylinder oil to insure that they will be properly lubricated when the power plant is first started after the refitting process is complete. The fitting is very easily done if the crankshaft is removed from the motor and held on a bench, as shown at Fig. 433.

Mixture Troubles.—Defective carburetion is usually indicated by misfiring or irregular operation. The common derangements of the components of the fuel system and the best method for their location follow: The first thing to do is to see if the fuel is flowing to the carburetor from the tank. This is done by disconnecting the feed pipe and seeing if the stream coming out is the full size of the orifice. If it trickles out slowly, it is an indication that either the pipe is clogged with dirt or that there is an accumulation of scale, rust or lint at the strainer screen usually placed in the tank over the gasoline discharge coupling. This may also indicate that there is not enough liquid in the tank. Insufficient fuel supply is sometimes due to the shut-off valve between the tank and the carburetor having jarred either partly or wholly closed because of vibration. If the stream of fuel from the tank indicates that it is reaching the carburetor all right, that device should be examined to see if there is any dirt or water in the float chamber. The float chamber of most carburetors may be drained by a petcock provided for the purpose. Dirt may constrict the passage between the flow chamber and the spray nozzle and very often the fine holes or spray openings in the latter may become blocked up by particles of foreign matter. The float may be binding and the gasoline needle valve regulating the supply opening in the bowl may stick to its seat. Any of these conditions would reduce the supply of fuel and the engine would not receive sufficient quantities of properly proportioned gas.

Some of the conditions that will produce poor mixture are: The air valve spring may be weak or broken, the gasoline or fuel adjusting needle may be loose and jar out of adjustment, the air valve spring adjusting nuts may be a poor fit on the valve stem and adjustments will not be retained, air may leak in through leaky joints of the inlet manifold or through holes of a porous casting; or the valve stem may have worn enough in the guides so air is drawn into the mixture through the worn inlet valve stem guide bushings. Any foreign matter in the fuel will cause irregular operation, because the standpipe bore may be partially constricted and not allow enough fuel to reach the mixture.

If clouds of black smoke are expelled from the exhaust pipe, it indicates that the fuel supplied the mixture is excessive and the supply should be reduced by screwing down on the needle valve in carburetors where this method of regulation is provided.

If no needle valve is used, the fuel proportions may be reduced by altering the fuel level in the float bowl. A pronounced "popping" in the carburetor means that the mixture contains too much air. If this is not due to air leaking in through worn valve guides or leaky manifolds, it may be overcome by screwing in the auxiliary air valve adjustment so the valve does not open so much, or by slightly increasing the fuel supply by opening up the regulating needle. The exhaust gas will be free from any objectionable odor and will be clean if fuel is not burned in excess. The character of the mixture may be judged by the color of the flame issuing from the exhaust pipe if the engine is run with an open throttle after dark. A red flame indicates too much gasoline, and a yellowish one shows an excess of air. A pronounced blue flame such as given by a gas stove or gasoline stove burner will indicate the properly-proportioned mixture.

Ignition System Derangements.—When a battery ignition system is provided and the engine does not run regularly, the first thing to look for is to see if there is a spark at the spark plugs. These members are removed from the cylinders and are then again coupled up to the secondary wire. They are laid on the cylinder castings in such a way that the bushing intended to be screwed into the cylinder is in good metallic contact, but the insulated terminal at the upper end out of contact. The engine is then turned over slowly by hand and the spark watched to see if there is any spark between the points. If there is no indication of current flow, the following may be looked for: A broken wire anywhere in the primary circuit, a defective ground connection, loose battery terminals, broken battery connections, lack of current at the battery.

Spark plugs may be rendered inoperative by cracked insulation or by deposits of carbon around the electrode. Secondary wires sometimes break or may become oil-soaked or have the insulation worn away, either of which permits the current to become grounded to some metal part of the motor. The electrodes of a spark plug may have burned away enough so the gap is too great or the points may be too close together. If there is no current at the spark coil the trouble may be due to broken timer wires, burned or pitted igniter contact points, vibrator out of adjustment, or poor connections at the commutator or timer.

If a magneto is fitted as an auxiliary supply of current, about the only thing that will cause failure of current generation outside of slipping or broken driving connections is that brush-holders may become fouled with old oil. Either of these conditions interferes with the flow of the current. The brushes may become worn so they no longer bear on the collector ring or distributor, and the current generated by the armature cannot be collected and sent to the outer circuit. Obviously, any derangement of the driving connections will interfere with current generation, because the armature will not be turned sufficiently regular or at the proper speed.

If a high tension magneto is fitted and no spark is produced at the plugs, the following defective conditions should be looked for: Broken secondary wires, current collecting brushes or distributor brush not making contact, contact points of the make-and-break device may be out of adjustment or covered with oil; the wiring may be attached to wrong terminals; the distributor filled with metallic particles, carbon dust or oil accumulations; the distributor contacts may not be making proper connections because of wear or a defective distributing brush, or more serious derangements may exist, such as defective windings or condenser, which fortunately are of extremely rare occurrence.

Cooling and Lubrication Group Faults.—Owing to the simplicity of the cooling systems ordinarily used, they are not liable to give trouble if the radiator or tank is kept full of clean water and the circulation is not impeded. The most common troubles producing defective cooling are due to impeded water circulation. A radiator may become clogged with rust or sediment and the piping or water jackets sometimes becomes filled with scale that tends to retard the flow of water. If the water pump or its driving means fail, circulation will not be positive and overheating will result, as is also evident if the cooling fan belt breaks or slips. When rubber hose is used in the circulation system, this may deteriorate inside and the area of the inside passages become reduced due to particles of rubber hanging down. The cooling system is often apt to overheat after anti-freezing solutions, of which calcium chloride forms a part, have been used, as crystals of the salt may collect in the radiator piping or water jackets. These crystals can only be dissolved by chemical means when in inaccessible places, but where the construction permits they may be removed by scraping. Overheating is sometimes caused by rich mixture and sometimes by defective lubrication.

When the oiling group is not working properly the friction between the parts of the mechanism usually produces heat. Poor lubrication usually results from: Not enough oil in the engine crankcase or mechanical oiler, oil of poor quality, broken or clogged oil pipes, broken oil pump or defective oil pump drive. The oil supply may be reduced by defective inlet or discharge check valves at a mechanical oiler or by worn pump-plungers in that device. A clogged oil passage or pipe leading to an important bearing point will result in loss of power and overheating because the oil cannot get between the working surfaces. Much of the trouble caused by defective oiling may be prevented by using only the best grades of lubricating oil, and lubricants of poor quality will cause friction and overheating, even if all parts of the oil system are working properly. If a mechanical oiler becomes inoperative or if its driving means fail while the truck is on the road, the engine may be kept in operation by putting enough oil in the crankcase so the connecting rods will dip into it as the crankshaft revolves. In most modern engines this will result in overoiling, but this is manifestly better than the other extreme, and the truck can be brought home under its own power.

Clutch Repairs.—After the engine has been overhauled, the clutch and transmission can be examined. The clutch casing of some heavy type trucks is attached to the engine crankcase; in others the clutches are not encased. By removing the cover plate of the clutch compartment that member may be examined if enclosed. If a dry disc type, as shown at Fig. 434, C, and it has been slipping, only adjusting is needed. There are usually three bolts through the plates of the clutch and the clutch itself. The clutch is a series of plates alternately steel, and that metal covered with asbestos on both sides, riveted firmly in place.

These discs require no oil or attention in any way except to avoid slipping the clutch as much as possible. A slipping clutch can be adjusted by the three adjusting nuts on the long bolts that regulate the spring pressure and that come through the face of the clutch. Turning them to the right will compress the spring and turning them to the left will loosen them. This operation is clearly shown at Fig. 434, A. Note whether the clutch throwout collar or bearing is worn. Sometimes through lack of lubrication this collar will wear so badly that the clutch pedal will chatter under the foot. If this is the case, a new

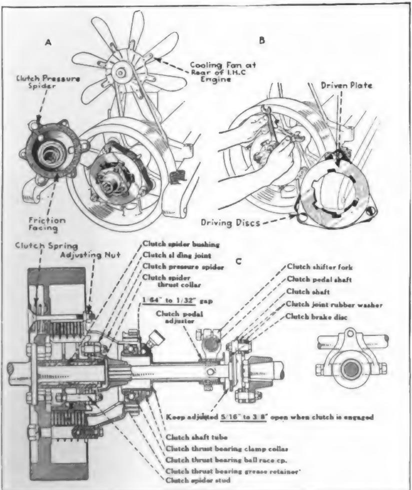

A
B
Cooling Fan at Rear of I.H.C Engine
Clutch Pressure Spider
Driven Plate
Friction Facing
Driving Discs
Clutch Spring
Adjusting Nut
Clutch spider bushing
Clutch sliding joint
Clutch pressure spider
Clutch spider thrust collar
1/64" to 1/32" gap
Clutch pedal adjuster
C
Clutch shifter fork
Clutch pedal shaft
Clutch shaft
Clutch joint rubber washer
Clutch brake disc
Keep adjusted 5/16" to 3/8" open when clutch is engaged
Clutch shaft tube
Clutch thrust bearing clamp collar
Clutch thrust bearing ball race cp.
Clutch thrust bearing grease retainer
Clutch spider stud

Fig. 434.—How to Adjust Clutch of I. H. C. Motor Truck Outlined at A and B. Sectional View Showing Construction Depicted at C.

guide for this collar can be put in without taking out the clutch in some designs, in others the clutch must be dismantled. See that the grease cups and this collar have plenty of grease.

A slipping cone clutch will need refacing. It will be apparent that as the clutch facing wears and the cone seats itself deeper into the female chamber that the spring tension may be reduced to some extent. In the clutch shown the spring pressure may be increased as desired by pulling out the split pins that keep the castellated adjusting nuts from turning and screwing each of these members in the same amount, endeavor being made to have the tension of all springs as nearly equal as possible. The clutch springs exert their pressure against the clutch cone at one end and the reaction is taken through the stud to a spider member between the clutch cone and the flywheel, which bears against a ball thrust-bearing carried by the crankshaft extension member.

The most common cause of faulty cone clutch action is some defect of the leather facing, as this may be packed down hard or charred by heat from slipping, or it may have been used so long that the leather has lost its life and becomes hard, with a glazed surface that has a very low degree of frictional adhesion. The clutch spring may have become weakened or broken: this will cause the clutch to slip, even if the leather facing is in good condition. The two troubles usually met with are harsh action as one extreme condition and power loss because of slipping as the other. If the surface of the leather lining becomes hard and does not have enough resiliency to yield slightly when first brought into frictional contact with a flywheel rim, this results in harsh engagement. To insure gradual clutch application the friction lining should be soft and elastic. If the leather has not been charred or is not worn too much, it may often be softened by rubbing it with neat's-foot oil and allowing that substance to soak into the pores of the leather. Kerosene oil is often enough to keep the clutch leather soft and pliable, and it has an added advantage in that it has so little lubricating value that the clutch members are not likely to slip because of reduced friction. Kerosene, also, has a quick penetration property that is valuable, and does not collect grit or gum. Cylinder or machine oil should never be used to soften a clutch leather.

When a cone clutch slips and the friction facing is not worn or the spring tension is not lessened, the trouble is usually due to a coating of lubricating oil on the frictional material, that reduces the friction so that the pressure of the clutch spring is not great enough to keep the clutch parts tightly pressed together in positive driving engagement. A simple remedy for this defective condition is to absorb the surplus lubricant by rubbing a small quantity of Fuller's earth into the leather surface. When a clutch cone is assembled it is not easy to reach the friction lining. The first step is to disengage or release the clutch and fasten the releasing mechanism in such a way that the clutch cone will stay out of engagement even when the pressure is released on the pedal. On some trucks of older designs the clutch release and emergency brake applying mechanism are interlocked so that applying the hand lever will release the clutch. The clutch may be held out of engagement in this case by latching the emergency brake lever. The Fuller's earth is placed on a piece of paper or card so it can be sprinkled into the space left between the male and female members. Powdered borax is often recommended for the same purpose. Rosin is sometimes advised, but this material should not be placed between the clutch members, as if there is any tendency to slipping and any generation of heat it may be melted and will become a lubricant that will intensify the slipping instead of acting to absorb the oil, as the Fuller's earth or borax will.

If slipping is caused by a broken clutch spring, which is a very rare occurrence, or by weakening of the clutch spring, which is more common, the method of repair is evident, this consisting of substituting springs of proper strength where no adjustment is provided or by increasing the degree of compression of the weak spring if some method of compensation for shortening the spring is included in the design. Another annoying condition when a cone or three-plate clutch is used or where the clutch-driven members are of large diameter and have considerable weight, is "spinning" or continual rotation of the male clutch member when the spring pressure is released. This is often due to inertia, but is sometimes caused by a defect in the clutch mechanism. If the plain bearing on which the cone revolves when disengaged in some clutches is not properly lubricated, or if a poor grade of grease is used for this purpose, the bearing may stick and the male clutch member will continue to rotate, even when the spring pressure is released. The ball thrust bearing employed to take clutch spring reaction, and which is clearly shown in the various sectional views previously described, may become wedged by a broken ball or particles of foreign matter, and if rotation of the parts relative to each other is prevented the rotation of the crankshaft will be imparted to the cone member through the clutch spring, which must turn with the crankshaft instead of remaining stationary, as would be the case if the ball thrust bearing were functioning as it should.

A seized clutch spindle bearing can only be repaired by taking the clutch apart and dressing down the scored journal, supplying a new bushing and removing the cause of the seizure. Sometimes when the clutch cone is carried on plain bearings, wear in these members will permit the cone to sag because of its weight, and even though the spring pressure is fully released the lower portion of the cone will come in contact with the flywheel and the cone will be kept in rotation. Faulty clutch action is often traced to points distinct from the clutch mechanism itself. This applies to all types of clutches. Many cases of failure of clutch to release have been found due to imperfect relation of interlocking levers or rods or depreciation in some mechanical parts. If the clutch shifting collar is worn unduly or the small pins in the rod yokes connecting the clutch pedal with the release mechanism have worn, the pedal may be fully depressed and yet the pressure of the spring keeping the parts in contact may not be reduced to any extent.

Whenever the dry plate clutch is used, one set of the series of discs is faced with some friction material, such as Raybestos, and, of course, when this facing wears, it must be replaced with new, just the same as advised for the cone clutch. These facings are usually of asbestos fabric, and must be procured woven in the special ring form of suitable dimensions for that specific make of clutch. It is not possible for the repairman or motorist to cut his own plate facing, as the material is hard to handle and there would be much waste if attempt was made to cut in segments from a wide strip of material.

Multiple disc or three-plate clutches are subjected to practically the same main troubles as found in the cone type, i.e., they will engage harshly or fail to transmit the engine power in a positive manner. If a multiple disc clutch of the all-metal plate type does not release properly, it is because the surfaces of the plates have become rough and tend to adhere together. The plates should be smooth and free from any rough particles or score marks, as these will always produce harsh engagement. This condition also results if there is insufficient oil or unsuitable lubricant in these types where the discs are designed to run in an oil bath. "Spinning" or continuous rotation of a multiple disc assembly often results from seizing due to gummed oil; the presence of carbon or burned oil between the plates, and in some cases by a lack of oil between the members. When an all-metal multiple disc clutch slips, this generally results because of reduced strength in the clutch springs, distortion of the plates, or the use of too heavy lubricating oil. To secure the best results from a multiple disc clutch it is imperative that only certain grades of oil be used. If one uses a cheap or inferior lubricant it will carbonize because of the heat present when the plates slip, or it will gum up owing to the admixture of animal fats or other adulterants.

In a number of cases faulty multiple disc clutch action is due to "brooming," which is a name given for a defective condition that exists when the sides of the keyway have become indented and prevent free movements of the plates, or when the plate edges become burred over and prevent full contact of the plates. In most cases the adjustment of a multiple disc clutch is easily accomplished by adjusting nuts that may be easily reached.

Looking Over Gearbox.—In examining the transmission, look for gears that are burred. This is a result when one tries to shift gears when the clutch is creeping or has not come to a complete stop. If the gears are badly burred at the tooth edges, it would be wise to take the transmission completely out of the frame. This generally may be done easily in motor trucks as the transmission is frequently amidship. Disconnect the rods leading to the gear shift levers and then disconnect the universal joints ahead and back of the transmission case. Loosen the bolts that hold it to the frame and remove the transmission from the chassis. The cover may be taken off by removing the small bolts holding it, as shown at Fig. 435, A, or the case may be separated into its two halves.

To remove the gears and shaft from the case first drive off the ends of the universal joints left on the shafts, using a block of wood and a hammer for this purpose. On each end of the case where the shaft comes through will be found a bushing or bearing held in place by a locking ring. Loosen and turn the locking ring to release it, then slip it off the shaft. Do the same

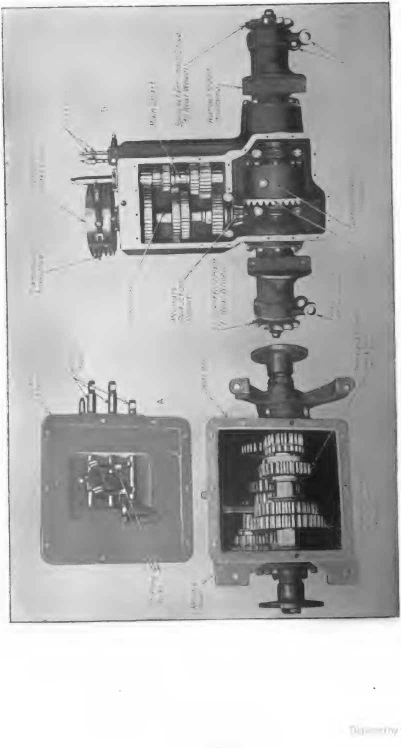


Fig. 435.—Typical Motor Truck Gearboxes. Form Shown at A is for Shaft Drive. The Combined Change Speed Gear and Countershaft Shown at B is for a Chain Drive Truck.

with the other end. With these ends removed the bearings can now be slipped out if they are of the anti-friction type.

To take out the main shaft of the usual selective type gearbox it may be necessary to disconnect the shifting forks. These are sometimes threaded onto their shafts, and can be turned to one side as they are lifted out of the collars on the shifting members. The shaft can now be slipped out. Put it in a vise and with a file dress off the edges of the gear teeth, if they are soft enough. If not, the burrs must be ground off. The gears on the lower shaft in the transmission case may be taken out and treated in the same manner. When putting the shafts back into the case, be sure that the bearings are in their proper seats and that the

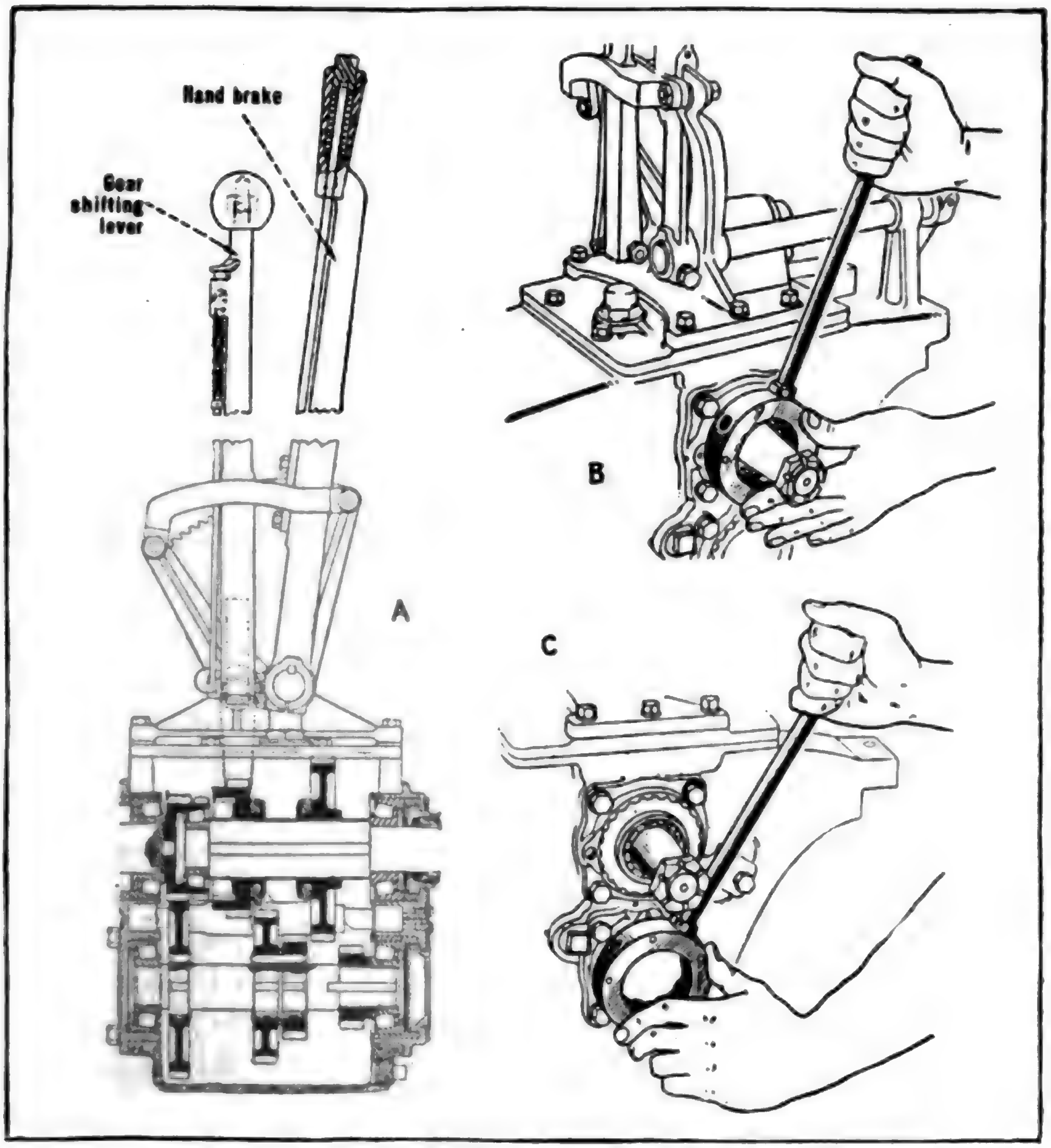


Fig. 436.—Simple Gearbox Used on I. H. C. Trucks.

locking rings are firmly seated and keyed. The sliding gear transmissions, as used in the great majority of trucks, are built upon the same general lines, some of them being assembled with the clutch and others placed amidships. Some types are placed in front of the jackshaft when a chain drive is used, as shown at Fig. 435, B, or in front of the rear axle in some types of bevel gear drives. Some of the transmissions have four speed ratios instead of three. Many of these are used in worm-driven trucks.

Transmission of I. H. C. Trucks.—The view of the transmission at Fig. 436 shows all gears in neutral position. The first, or lowest speed, is obtained by throwing the hand lever into the position marked "L" on the quadrant. This brings the large gear on the square shaft into mesh with its pinion on the countershaft, and power is transmitted through the constant mesh gears to the countershaft and through low speed gears to the squared shaft which carries the rear universal joint. The second speed is obtained when the hand lever is in quadrant position "M," when the smaller sliding gear is in mesh with the large gear in center of countershaft. Third, or high gear, is obtained with lever in position "H," when the drive is direct through the internal gear clutch on the forward sliding gear and the countershaft turns idly. In reverse, the gear shifter lever is in position "R," and the large sliding gear meshes with an idler pinion which in turn meshes with the small pinion on the countershaft.

Timken roller bearings are used throughout, and those on the main shafts are adjusted by the spanner nuts just outside the case at the front end, and by turning the notched plate outside the rear bearing, either one adjusts the entire series. The notched plate turns to the left to tighten bearings. Be sure that locking plates are in position so as to hold the adjustment before leaving the job. The inside horned nut at the rear end is a packing device. The countershaft bearings are adjusted at the rear by the same kind of device as used on the main shaft. Great care must be taken not to get bearings adjusted too tight.

The Rear Axles and Shafts.—The rear system of the truck should be given some attention. There are several different types of axles in use in trucks, and the adjustments of these differ. For instance, there is the bevel gear drive that is used in many of the light trucks up to a ton-load rating. Then there is the internal gear drive which has the secondary drive pinions

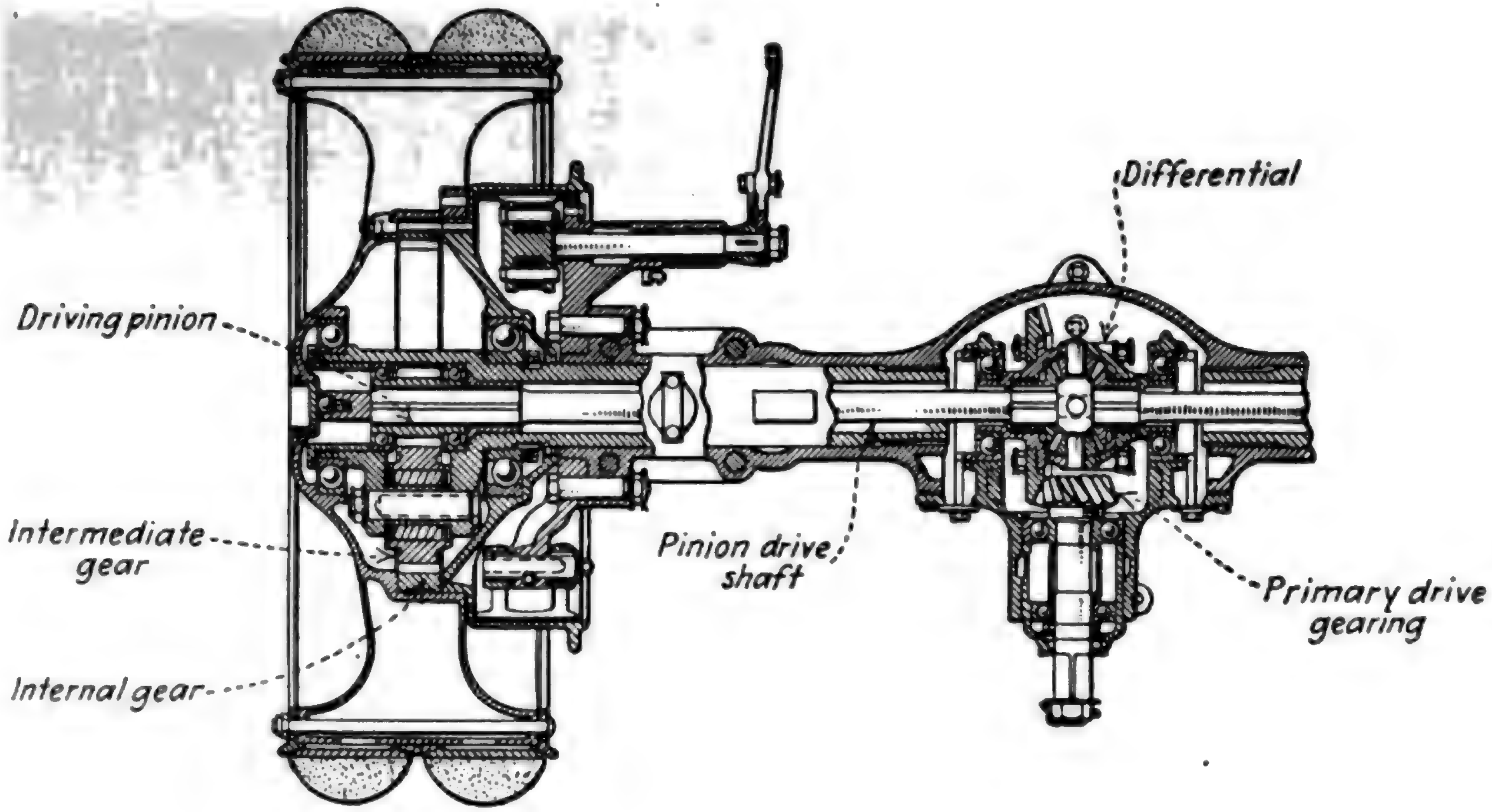

Driving pinion
Intermediate gear
Internal gear
Pinion drive shaft
Differential
Primary drive gearing

Fig. 437.—Internal Gear Drive Axle Employed on Large White Trucks Uses Intermediate Gear Between Driving Pinion and Ring Gear.

and the internal gears inside the brake drum. This type is used in trucks from one ton to seven tons capacity, and on some of the four-wheel driven trucks. The worm drive is used in a very large part of trucks from three-quarter ton to six and seven tons load rating. Last of all is the chain drive, from sprockets on the end of jackshaft to a sprocket on the rear wheel, using a dead axle to carry the load.

In the bevel gear type of axle look for worn bearings on the axle shafts, and each side of the differential. If these are good standard bearings at the start, such as a roller or ball type, they will not require much attention. If they are worn to any extent they should be replaced with new. If the differential gears show wear or are chipped on the edges, remove them and either grind them off smooth or replace them with new gears. This applies to the pinion and ring gears only. The gears of the differential assembly rarely need attention unless the truck has made an unusual mileage and show excessive wear. In that case they should be replaced with new.

The internal gear drive principle is similar to the bevel drive differential gearset as relates to primary reduction, but from this to the wheels the principle is quite different. The primary reduction gears in the differential housing are nearly the same size. The load is carried on a dead axle, the axle housing simply carrying the driving axle. The final drive is by one or more pinions on the shafts to an internal gear in the brake drum of the wheel. The internal gear drive axle of the White truck is shown at Fig. 437, and is an exceptionally good design.

How to Adjust Gears in Timken-Detroit Rear Axles.—There are three conditions which make adjustment of gears advisable. These are: 1. Objectionable noise. 2. Excessive back lash. 3. Looseness between bearings on pinion shaft or at the differential.

First.—Before making adjustments for elimination of noise or back lash, take up all looseness, if any, in bearings. To do this, remove bolts "A" (see Fig. 438) and locking key "B." Turn slotted ring "C" toward right, while holding ring "D" in its original position, until bearings are free from end play, at the same time allowing pinion shaft to turn free. To take up differential bearings, remove locking wire in cap screws "L" and loosen screws one-half turn. Release locking finger "J" and turn right-hand adjusting ring "F" toward differential until bearings are free from end play, at the same time allowing differential to turn freely.

Second.—When adjusting to eliminate noise, remove bolt "A" and locking key "B," as above, and turn rings "C" and "D" one slot toward the left and repeat until quietest point is found. If noise increases, adjust in the opposite direction. Always turn rings "C" and "D" together when adjusting for this purpose by using a tool broad enough to engage slots in both rings.

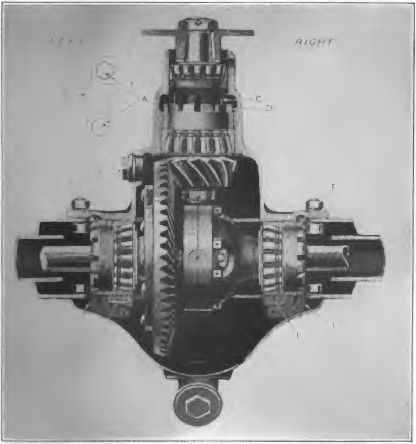


Fig. 438.—Speed Wagon Axle Using Timken Roller Bearings.

Third.—When adjusting to take up backlash in gears, remove wire and loosen cap screws "K" "L" one-half turn. Release locking fingers "H" "J." Back adjusting ring "F" away from differential and turn adjusting ring "E" toward differential (right-hand thread on both) until gear is forced toward pinion so that it has about .005" backlash, or barely perceptible looseness.

If gears are so far out of mesh that no results can be obtained through method described above, or new gears have to be placed in axle, remove peep hole plug "G" for observation, and set gears with backs flush, as a starting point, and proceed again as above. If noise results from taking up loose bearings, proceed as in paragraphs two and three, as required.

After making adjustments, make sure that all locking keys, cotters, wires, etc., are replaced, and all bolts and cap screws properly drawn up. If running a car to try effect of any adjustments, all bolts and cap screws must be properly tightened. These instructions apply particularly to rear axles illustrated. Other rear axles made by this company differ slightly in construction from these, but in a general way the method described above can be used for other axles also.

The bearings and gears in this type axle should be examined for wear. When excessively worn the restoration had best be made by putting in new parts wherever needed. The worm drive system should be examined as to the conditions of the bearings, and also as to the wear in the worm shaft and worm wheel. If a worm drive is not properly lubricated, excessive wear takes place at the worm. If the worm wheel is worn considerably or the worm shaft is cut or scored, replacement may be necessary. The bearings may require renewal if much worn. In the chain drive the chief places for wear to show are the chains and sprockets. If the sprockets are worn they can be reversed and considerable wear obtained from the other side. If the chains are worn or stretched they should be replaced with new. Keep the chains well oiled and when in use they will run fairly quiet. Chains must be kept clean.

The axles used in truck construction may be divided into four classes: the semi-floating axle, which is used in light trucks; the three-quarter floating and the full floating, and the dead axle, used in all of the chain drive types and in the internal gear drive type trucks. All of these have been fully described in the chapter on final drive systems.

The brake shoes should be examined for depreciation, and if worn too badly should be relined and adjusted. Tighten all loose bolts and nuts on the frame of chassis and guards. See that sufficient lubrication is supplied to the differential. A good grade of steam cylinder oil can be used for this, filling the case to the peep hole on the side of the case. The reason for using a heavy oil in preference to grease is that it clings to the face of the gears and lubricates them thoroughly. Where grease is used the master gear may cut a path in the grease and the pinion gear will not be lubricated. Keep the grease cups full and turn them down once every other day, if necessary. Make this a practice and it will save uncertainty on the part of the driver.

I. H. C. Rear Axle.—The rear axle which is shown at Fig. 439 is of the internal gear type. The load is carried on a drop-forged, heat-treated alloy steel solid axle, while the power-transmitting mechanism is enclosed in oil-tight castings. The wheels run on Hyatt roller bearings and end motion is taken by hardened steel and bronze thrust bearings. The hubs have integral flanges, supporting and driving the spokes, and carrying the internal gear rings which are pressed into place, locked by four round keys and secured against slipping out by an expansion ring.

How to Remove Internal Gear.—To remove one of these gears: first, pry out locking ring; next, pry or pull out the gear, as shown at Fig. 440. Insert the new gear, using partly inserted round keys to locate the gear with reference to the keyways, and drive gear and keys home with a soft hammer or by using a block of wood to strike against. See that the locking ring is down in its groove and cotter pin inserted in hub rim and ends well spread so that the locking ring cannot work out. All this work can be done by anyone handy with ordinary tools, and it is not necessary nor advisable to buy a new hub with gear attached, as was the case with the old design.

Lubrication of the Axle.—The wheel hubs should be packed with a heavy grease for summer, using a little lighter grease for winter. More can be added as necessary by removing and filling the hub cap. Care should be used not to overdo this, as excess grease working out into the gear compartment in too great quantity will get onto the brake. The best grease for the internal gears is the kind that sticks to the surfaces. Cover the teeth and put a little in the cavity behind them. Look at the gears after the truck has run 2,000 miles; see how much grease is left and how much has worked out onto the brakes and govern your use of lubricant accordingly. A heavy steam cylinder oil, such as 600 W. for winter use, or a nonfluid transmission oil, or semi-fluid grease for summer, are right for the differential case. No.

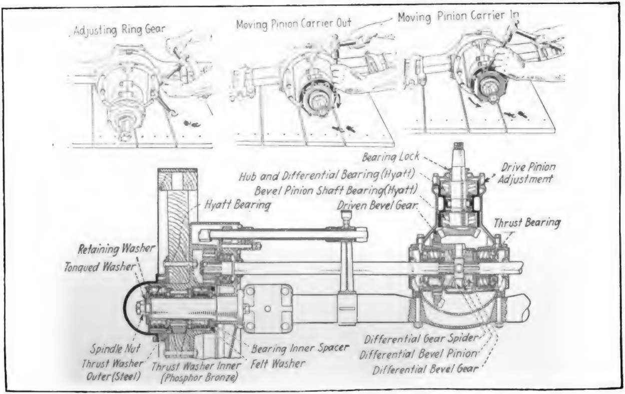
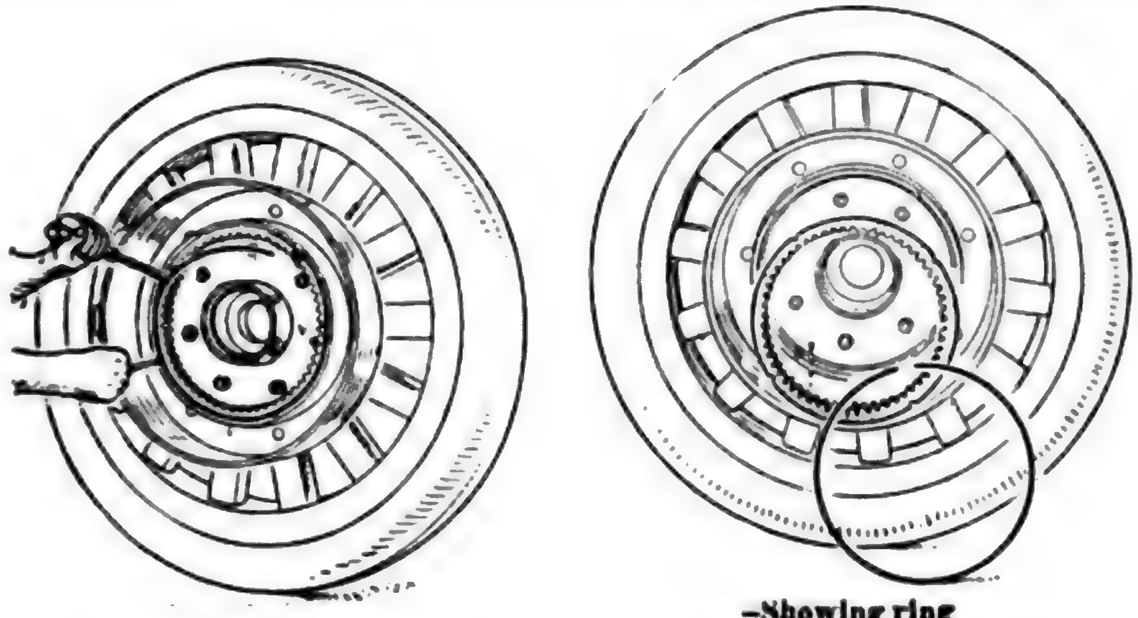

Adjusting Ring Gear
Moving Pinion Carrier Out
Moving Pinion Carrier In
Bearing Lock
Drive Pinion Adjustment
Hub and Differential Bearing (Hyatt)
Bevel Pinion Shaft Bearing (Hyatt)
Hyatt Bearing
Driven Bevel Gear
Thrust Bearing
Retaining Washer
Tonqued Washer
Spindle Nut
Thrust Washer Outer (Steel)
Thrust Washer Inner (Phosphor Bronze)
Bearing Inner Spacer
Felt Washer
Differential Gear Spider
Differential Bevel Pinion
Differential Bevel Gear

Fig. 439.—Diagrams Showing Construction and Adjustment of I. H. C. Truck Axle.

41 Gredag is good. The case should contain about two quarts and should have attention every 2,000 miles, or oftener if there are signs of loss of lubricant from the case.

The Universal Joints.—Lubrication: The joints should be filled with grease about every 1,500 miles. Unscrew two of the pipe plugs closing the outer ends of the bushings in which the cross trunnions work, as shown at Fig. 441. Force grease into one bushing with a grease gun until the central cavity of the cross is full and grease is forced out through the other unplugged opening. Screw both plugs back tight. Lubricate the splined shaft with grease gun through the hole in the side of the yoke. Be sure to screw plug back tight. Use transmission grease in winter and a medium cup grease in summer. Grease must not be too hard. To remove bushings, take caps off the yokes and bushings can be removed readily. When replacing parts see that the felt washer retainer is next the yoke, so that parts will slip together readily. Screws holding caps must be turned up tight with lock washers under heads and wired.



—Showing how to pry out gear locking ring.

—Showing ring and internal gear removed.

Fig. 440.—How to Remove Ring Gear from I. H. C. Truck Axle.

To Adjust Bevel Gears.—The bevel gearing is carefully adjusted when it leaves the factory and, if kept properly lubricated, should not need attention for a long time. Do not take it apart as long as it runs quietly. If it should become necessary to inspect it, the entire gearing can be taken out without altering its adjustment, as directed below, but adjustment can be made with the gearing in place. A grease cup is provided for the bearing at pinion end of each driving shaft. Give each cup a turn every 100 miles. Use no grease containing acid nor animal fat. Vaseline is good. Remove drive shaft packing plate and back off the lock screw on each side of the differential housing, the adjusting ring is then accessible through openings in the housing. These rings adjust the bevel gear sidewise, and take up any play in the thrust bearings.

The bevel drive pinion is adjusted by the drive pinion adjustment cap shown at Fig. 439. Remove the cap screws locking this piece. To back the pinion out, turn this cap to the right. To force it in, turn to the left; this screws back on the bearing carrier. Put the lock screws back in and draw up, forcing the pinion and bearing assembly forward. There are three tapped holes close together for each screw so that a close adjustment can be made. Pull the cap hard against the case with the lock screws.

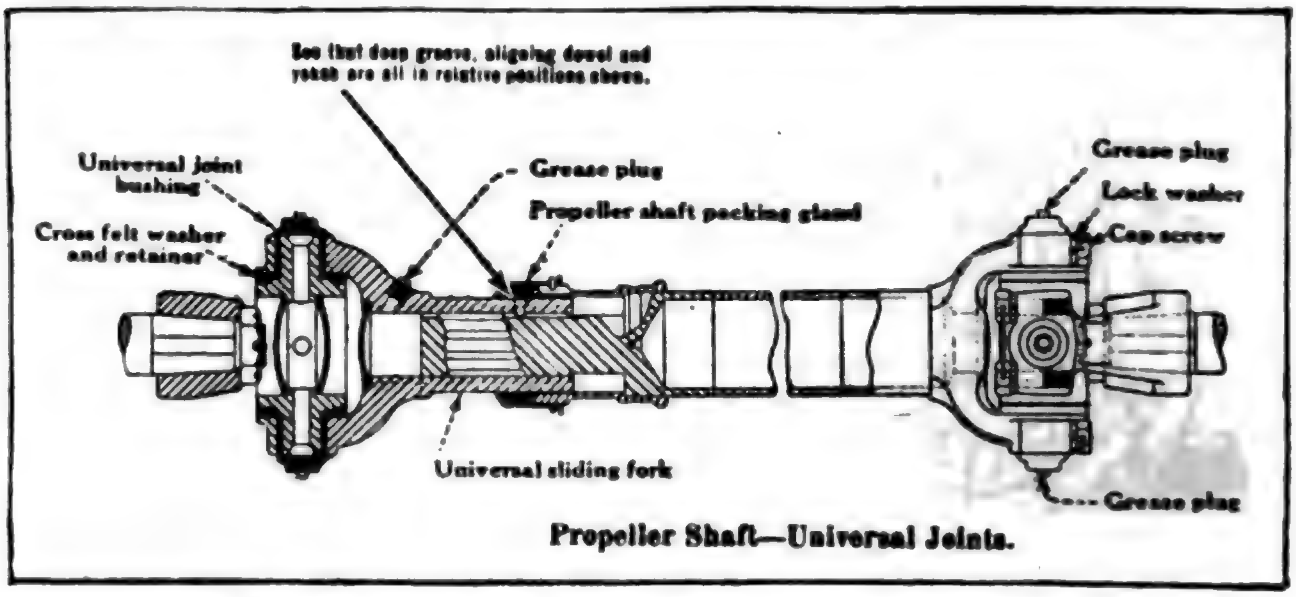

See that deep groove, aligning dowel and yokes are all in relative positions shown.
Universal joint bushing
Cross felt washer and retainer
Grease plug
Propeller shaft packing gland
Universal sliding fork
Grease plug
Lock washer
Cap screw
Grease plug
Propeller Shaft—Universal Joints.

Fig. 441.—I. H. C. Truck Universal Joints.

The best way to determine whether the adjustment is perfect is to cover the teeth of one gear with a light coating of Prussian blue and then, after assembling, turn the gears a few revolutions. When the blue is transferred to the other gear uniformly, from end to end of the teeth, the adjustment is right. Be careful to have the adjustments securely locked before assembling finally and be particularly careful that there is no pressure exerted by the adjusting nuts on the thrust bearings. If there is, you may have to take the axle down again shortly and put in new bearings. The notched nut adjusts the thrust bearings only. While an experienced man can adjust the gearing without removing it, it is much more readily done by getting it out where it can be seen. To do this, jack up the axle, remove the wheels, remove the bolts fastening bearing retainer to brake anchor, and pull out drive pinion and shaft. Unbolt the gear carrier from the housing, when the carrier with the assembly gears can be pulled forward. Do not remove bolts holding the housing to the axle. In replacing the wheels, screw the axle nut up hard and lock with cotter.

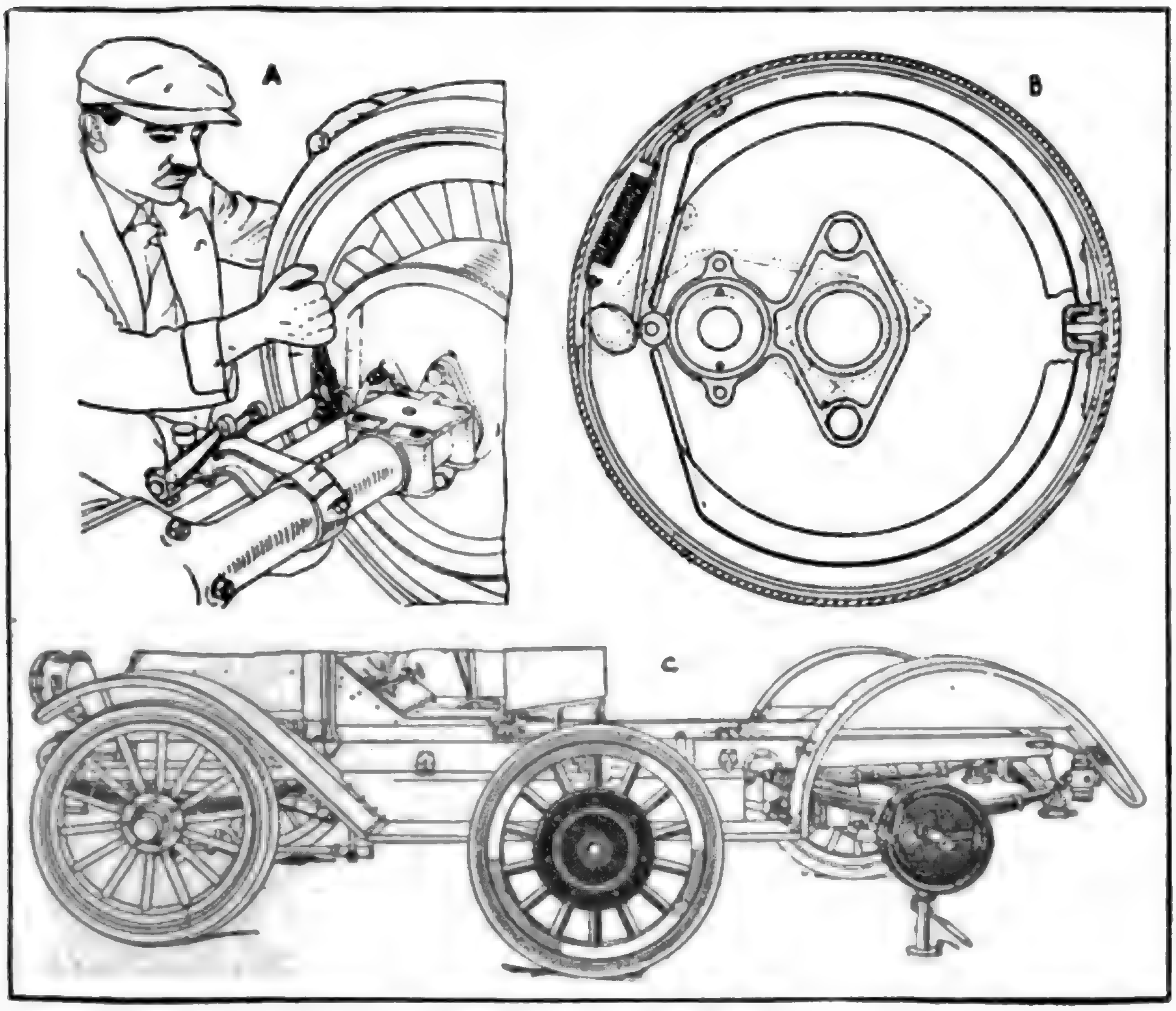


Fig. 442.—How to Adjust I. H. C. Truck Brakes.

Worm Drive.—On many truck models, the differential drive units are of the worm gear type. The propeller shaft and universal joint are connected direct to the worm shaft. Should occasion arise necessitating adjustment, this should by all means be taken care of by one experienced with rear axle alignment. In order to make adjustment on the driving-worm shaft, it is necessary to disconnect the universal joint from the wormshaft. Then remove the nuts, which hold the worm cover to the axle housing and the axle shafts. This will permit you to lift the

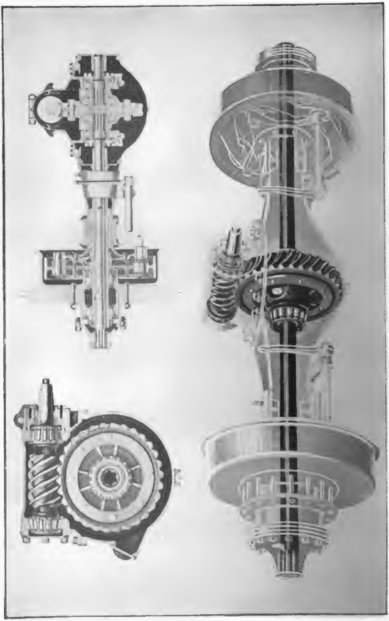


Fig. 443.—Worm Drive Axles Using Timken Roller Bearings.

worm assembly from the housing. The construction of a typical worm drive axle is clearly shown at Fig. 443.

The adjustment for the worm is made at the front end only of the shaft by turning the adjusting nuts. It is necessary that the shaft have about one-sixty-fourth of an inch to one-thirty-second of an inch end play. It is also necessary that the drive worm-wheel is in the center of the wormshaft and the adjustment be made by the adjusting nut at bearing ends. The differential and its gears in the worm-drive type should require no attention other than keeping the housing filled with a readily flowing lubricating oil, free from acid and graphite. Inspections should be made weekly and fill oil in the housing, even with the filler. Replace oil every 1,000 miles.

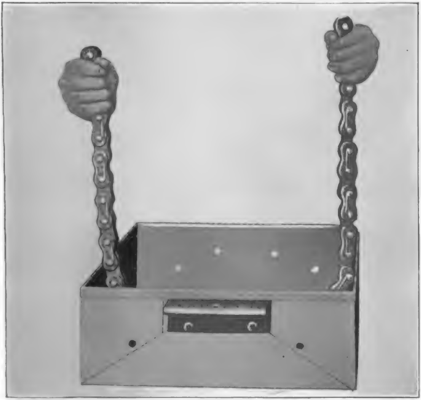


Fig. 444.—How to Clean Driving Chain.

Chain Drive.—On models constructed with chain drive the differential is located in a jackshaft housing, as shown at Fig.

435, whereas in the worm drive it is housed directly in the rear axle, as clearly shown at Fig. 443. The differential in a number of models is of a nonadjustable type, and is shimmed in proper place when assembled at the factory. The shim is found between the spacer and the jackshaft housing end of the left side.

To remove the differential, take off the bearing caps on the front and rear end of the countershaft. Tap the bearing out of position with a lead mallet and pull the countershaft forward, then remove both the hackshafts by removing chains, take out the wire lock found near the radius rod collar, and turn out jackshaft housing end, thus removing the jackshaft. Remove the differential bearing carrier caps and lift out the differential.

Keep the transmission and differential housing filled to three-quarters full of the good grade of heavy fluid grease, of the consistency of 600 W. Once every season the housing should be thoroughly cleaned of all grease and accumulated grit and refilled.

Care of Chains.—Chains should first be thoroughly cleaned of all dirt and grit by thoroughly soaking in gasoline; then make a mixture of beef tallow and flake graphite, using three parts of tallow and one part of graphite. This lubricant should be put in a pan, as shown at Fig. 444, and heated almost to the boiling point, and then, while the lubricant is still hot, draw the chains slowly back and forth through it until all the joints have been thoroughly oiled. Next lay the chain full length on the floor or on a bench, and push the links together to make the chain as short as possible, then leave the chain undisturbed until the grease has become set or hardened.

This not only results in the chain being thoroughly lubricated, but, by allowing the lubricant to dry, as referred to, it serves to protect rollers from dust and grit. One other point in the caring for chains which is seldom given the proper attention is the cleaning or brushing off of all heavy dirt or dust which accumulates after the truck is driven in rain or through mud When this is done (and it should be quite often to prevent the dirt from getting into the joints and cutting the bearings), the best method of accomplishing it is to jack up one wheel, start the motor and then put the gear-shift lever in either first speed or reverse.

Then let the clutch in and allow the wheel to turn. While the wheel is revolving take a stiff brush and brush the chain vigorously, being careful not to get hands or brush between the chains and the sprockets. Whenever the truck is run this way with one wheel jacked up, be sure to block the other wheels well, so that the truck cannot fall off the jack.

While the above-mentioned method of lubricating chains is by far the best method, at the same time there are a great many cases where it would be impossible to change this lubrication, and for that reason a simpler method, although not nearly as satisfactory, may suffice. If chains are cared for as described below, and then occasionally taken off as mentioned above, they will last a great deal longer.

Jack up the rear wheel and clean the chains and sprockets as thoroughly as possible with a stiff brush, turning the wheels by hand as may be needed, then wipe with waste. Then start the motor and shift the gear lever to reverse or first speed, so the rear wheels turn very slowly. Now, as the rear wheels revolve and the chains are moving, squirt gasoline on them, which will cut away the dirt inside and out. When the chains are thoroughly cleaned stop the motor, take grease, preferably one that contains graphite, and apply with a brush all over the chains, turning the wheels so as to work the lubricant into the rollers.

This last is very important as the friction is inside of chains, there being a roller action between the rivets and the roller of the links. Work grease between the rollers and side links, then wipe off the surplus grease.

Care of Brakes.—There is not a part of a truck more neglected by the average driver than the brakes; they are of the utmost importance, however. There should be no disregard of the precautions necessary to insure their dependable condition at all times. Both sets of brakes are smooth and positive in action, and under ordinary usage will not require any particular attention other than occasional oiling of the connections and the regular usage of the grease cups provided for the brakeshaft bearings. All working joints, at clevis ends, should be kept free in action by an occasional oiling, and the rods kept free from lost motion.

Both sets of brakes in most trucks are equalized, but this must not be misunderstood to mean that whether the brake be properly adjusted or not the action will be alike for either wheel. On the contrary, it is important to see to it that the brake shoe or brake band clearance be maintained uniformly for both brakes.

This is particularly true of the band brakes where such are used. In adjusting the free ends of the band type of brake, particular attention must be paid to the clearance as well as to having the two ends of either brake come in contact with the drum evenly. It is very important when brake adjustments are made that extreme care be taken to see that there is no drag, as a dragging brake not only wears out rapidly, but also absorbs considerable power. When the play in the brakes becomes more noticeable, it may be taken up by shortening the rods in some trucks by means of the threaded joints, which are then screwed into their clevises the required distance.

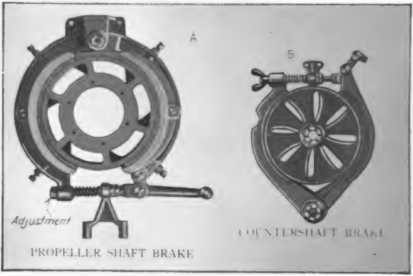


Fig. 445.—Types of Shoe Brakes Used on Propeller Shafts and Countershafts.

Service Brake.—On some truck models the service brake is installed on the countershaft of the transmission. Operation is from the foot pedal. This brake is of the external-contracting type, and except for the nonadjustable anchor pin is in all respects as far as adjustment and maintenance is concerned similar to other models. The propeller shaft brake is usually of the locomotive type, as shown at A, Fig. 445. The shoes are of the swiveling pattern, mounted on swinging arms, which in turn are operated by a balance linkage, insuring that the pressure applied for braking be applied evenly.

When adjusting the propeller shaft brake of Garford trucks, it is best that the four set screws bearing against the brake shoes be released entirely and that the brake be drawn up for action and retained in such position before the four set screws are again brought to bear against the brake shoe. It is important that the screws be brought down evenly, and only until contact is made with the shoe, after which the check nuts may be brought to bear. There is absolutely no cause for frequent adjustment of these set screws. To compensate for wear of the brake lining, the nut attached to the draw-stem should be given a turn or two, after which an inspection of the shoes must be made to ascertain if contact with the drum is made.

On practically all worm-driven models one set of brakes are of internal expanding shoe type. This particular type of brake requires a very small amount of attention and invariably will give entire satisfaction until the lining is completely worn out. It is for this reason that no adjustments are provided on the free ends of the shoes. The only adjustment which will ever be required after the facings have worn is that which can be effected by shortening the brake connecting rods by your changing the position of the brake cam levers on the brake camshafts until you get the desired adjustment. You can loosen the lever and move it back a notch at a time from its original position, being careful when doing this to change the mating lever on the opposite side of the axle. Care should be exercised in making brake adjustments that the brakes do not drag, as a dragging brake not only wears out rapidly, but also absorbs considerable power. On some models the rear wheel brakes are of the twin pattern. Only one set of the twin shoes are connected, due to the use of the propeller shaft brake for service. When one set of shoes are worn out, the control rods may be placed on the free brake shoes and used until it is necessary to reline all at once.

Pierce Truck Brakes.—The service or foot brake (Fig. 446), operated by the pedal, is of the locomotive type, and consists of two contracting shoes operated on a drum at the rear of a transmission. These brake shoes are lined with a special fabric, and should be examined from time to time to see that the surfaces are not worn away. In adjusting the foot brake it is merely necessary to tighten up the large nut "1," at the left end of the foot brake camshaft. This nut can be easily located, due to the fact that it is held in position by means of a flat steel spring "2," and in order to turn this nut it is only necessary to lift this spring up slightly. It may be found after the brake has been adjusted a number of times that the left shoe—looking forward—is close against the drum. In this case it will be necessary to move the cottered nut "3" several turns, care being taken to replace the cotter pin after this adjustment. Care should always be taken in adjusting this brake to see that both shoes are perfectly free of the drum when the brake is released. By withdrawing the two demounting pins "4," Fig. 446, A, held in place by cotter pins, both brake shoes can be removed for replacement or relining. If this service brake is found to act somewhat

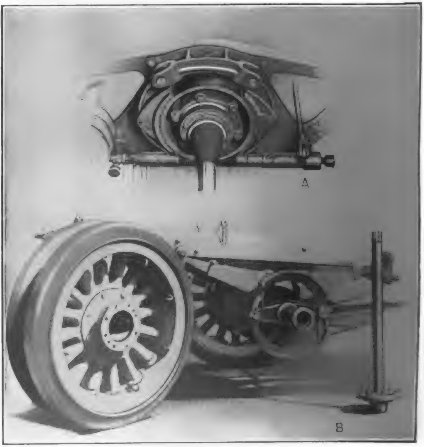


Fig. 446.—Brakes of Pierce-Arrow Truck.

harshly at times, its action can be softened by rubbing a little graphite grease over the brake drum. This does not destroy the efficiency of the brake, but prevents the harsh gripping.

The emergency or hand brake (Fig. 446, B) is of the internal expanding type and acts on the drums of both rear wheels and is operated by a hand lever at the side of the truck. The brake shoes are pivoted at the rear ends and the grease cups for the lubrication of these pins "1" should be given a turn every day the car is in use. There is also a grease cup for cam spindle "2," which should be given a turn every 150 miles. All joints and connections from the brake pedal and hand lever to the toggles operating the two sets of brakes should be kept clean and lubricated daily.

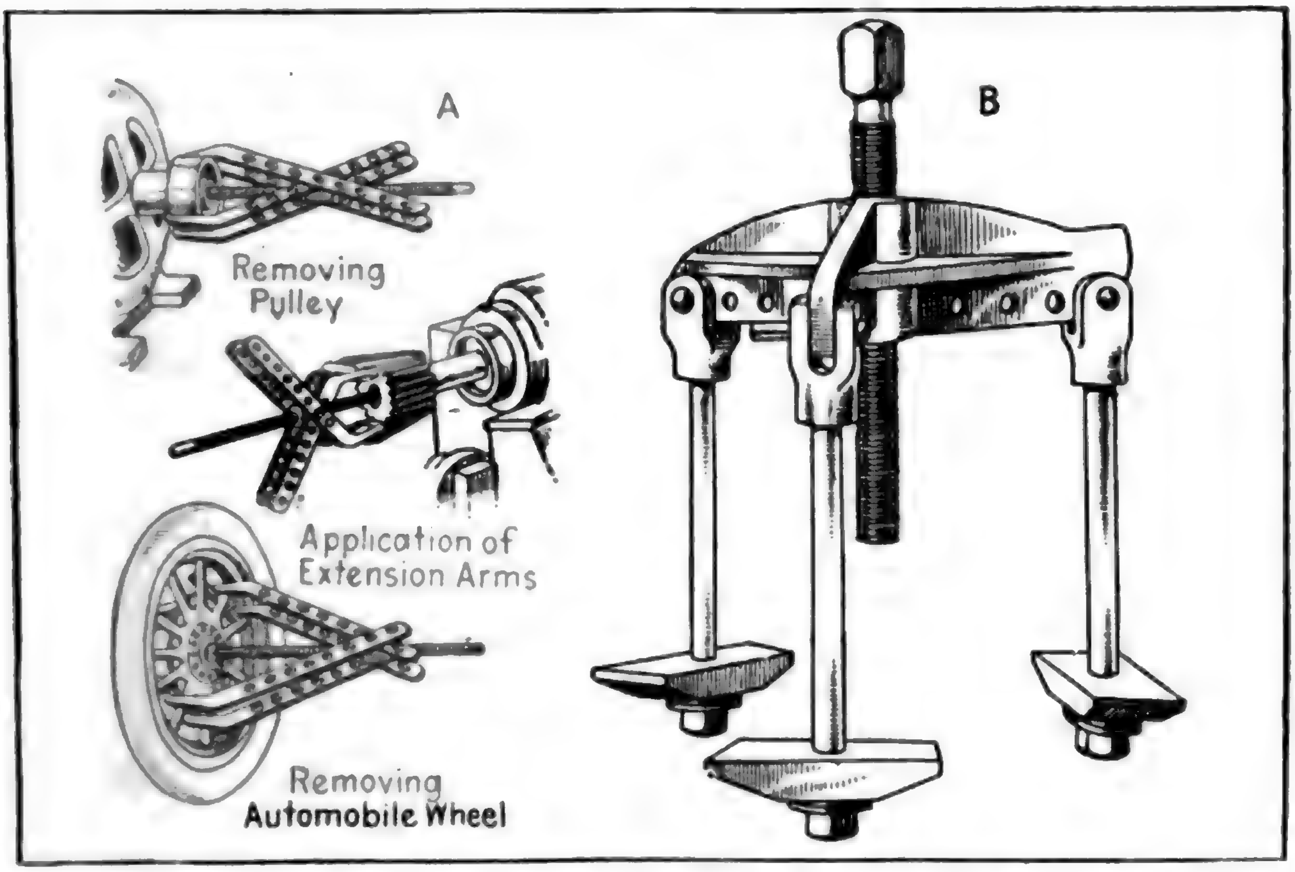


Fig. 447.—Wheel Pullers Used to Remove Wheels from Axles so Internal Brakes May Be Reached.

The hand brake is adjusted by means of the adjusting yokes at the forward ends of the brake rods. There is a compensating device which equalizes the braking action on each rear wheel; however, in adjusting these brakes it is advisable to turn up the adjusting yokes the same number of turns in both sides of the truck. In the same way care should be exercised not to adjust these brakes too tight. When the truck is empty, the hand brake should not take hold until the third notch; otherwise, when the truck is loaded, the radius rod action will cause "dragging." If it is suspected that the brakes are dragging, jack up each rear wheel in turn—with the truck loaded—and spin them around by hand, which will indicate the adjustment of the brakes. Be careful to keep all brake surfaces free of oil and grease, unless where conditions exist as stated above. The brakes should never be so loose as to allow them to be applied to the full extent of travel.

Gear and Wheel Pullers.—A tool that has much utility is the "Little Giant" gear and wheel puller shown at Fig. 447, A, and is very useful in removing wheels for working on the brakes when these are keyed to live axle shafts. It is made with four puller arms of dropped forged steel and has an adjustment range from zero to 13 inches when "extension arms" are used. The puller arms are so arranged that with the draw screw in place there are four pulling points, so distributed that there is no need of a holding or steadying bar. The pulling prongs are designed to give maximum strength, yet to occupy little room. For this reason they may be used for removing timing gears or other gears where room is limited.

This device is handy for removing inside work and for inside pulls. For removing small pulleys or gears a pair of extension arms may be used. These arms are provided with a locking arrangement for fastening to the pulling arms and provide for two pulling points rather than the four as in the primal attachment.

The Crane three-arm puller shown at Fig. 447, B, is especially valuable in removing motor truck wheels, as it is very substantial in construction. There are pads on the ends of the puller bolts which swing from the arms, these fitting back of the spokes. The puller bolts have yokes on the end to fit the arms and their location may be changed to conform to pieces of varying diameter they are used with. The advantage of a three-arm puller over a two-arm is that it cannot rock to one side or the other as the screw is tightened, and its pressure is always applied at equidistant points from the center pressure screw.

Wheel Alignment.—The front wheels of practically all models, when correctly aligned, are not exactly parallel, but "toed in." In order to make the steering easy and to keep the front tires in position so they will wear evenly, you should occasionally examine the front wheels to see that they line up correctly. It is good practice to "toe in," as it were, the front wheels anywhere from one-quarter to one-half of an inch in front. That is, the inner edge of the rim in front should measure about one-half inch closer together than at the rear. These measurements are to be taken in line with the hubs at diametrically opposite points. Take a stick the exact length from one rim to the other, across the front of the wheels, then put the stick between the wheels at the rear, and if you find the distance to be one-quarter to one-half of an inch greater than the length of the stick, the alignment is all right. In case it is not, you should remove the bolt that holds the cross rod between one steering arm and the other and turn up or turn off, as the case may require, the adjustable clevis until you have the proper distance.

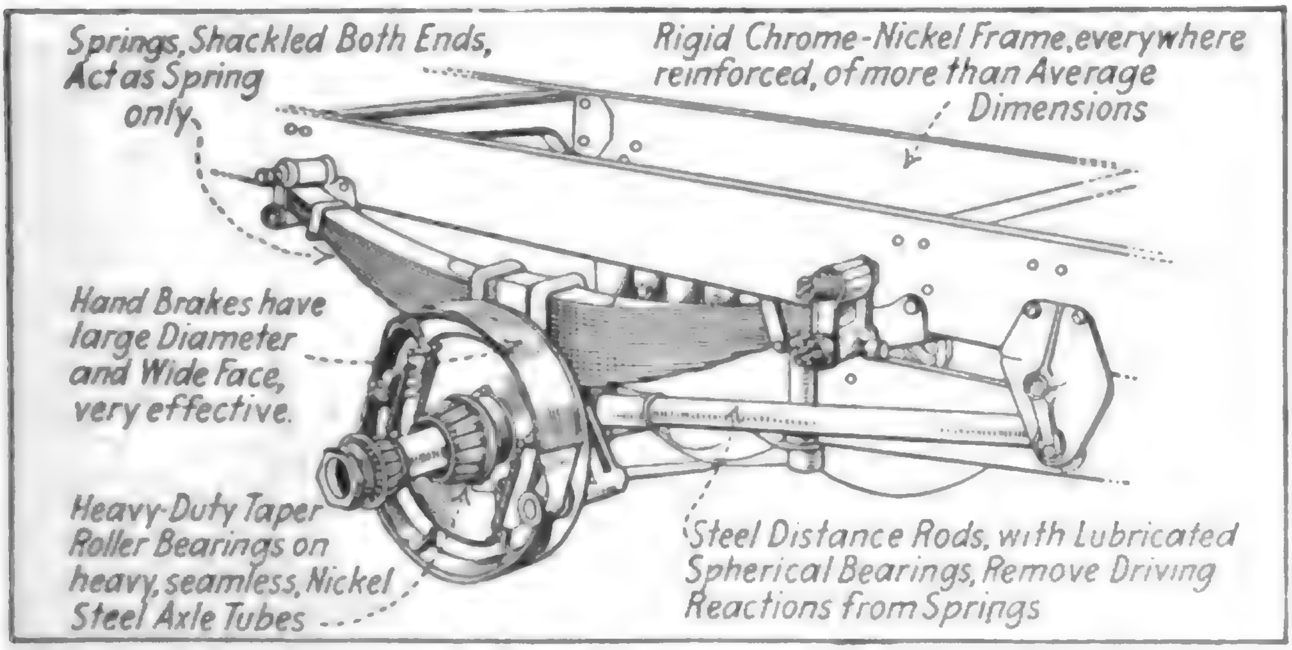

Springs, Shackled Both Ends, Act as Spring only
Rigid Chrome-Nickel Frame, everywhere reinforced, of more than Average Dimensions
Hand Brakes have large Diameter and Wide Face, very effective.
Heavy-Duty Taper Roller Bearings on heavy, seamless, Nickel Steel Axle Tubes
Steel Distance Rods, with Lubricated Spherical Bearings, Remove Driving Reactions from Springs

Fig. 448.—Truck Axle with Wheel Removed Showing Internal Brake and Taper Roller Bearings.

The wheels of most truck models are equipped with taper roller bearings, which are the most durable and easily adjusted. To keep the bearings well lubricated, pack them with grease (not graphite grease). To see whether the wheel bearings need adjustment, jack up the wheels, when any looseness will show on rocking the wheels sideways.

Care and Adjustment of Wheel Bearings.—Remove the hub cap, then put a jack under the front axle, and raise the wheel clear of the ground.

Wipe the grease from the end of the front axle spindle and with your pliers remove the cotter pin from in front of the outer lock nut. Take off the outer lock nut with a wrench. A thin lock washer comes off next, then take off the inner lock nut. Kneel directly in front of the wheel. Grasp the rim of the wheel

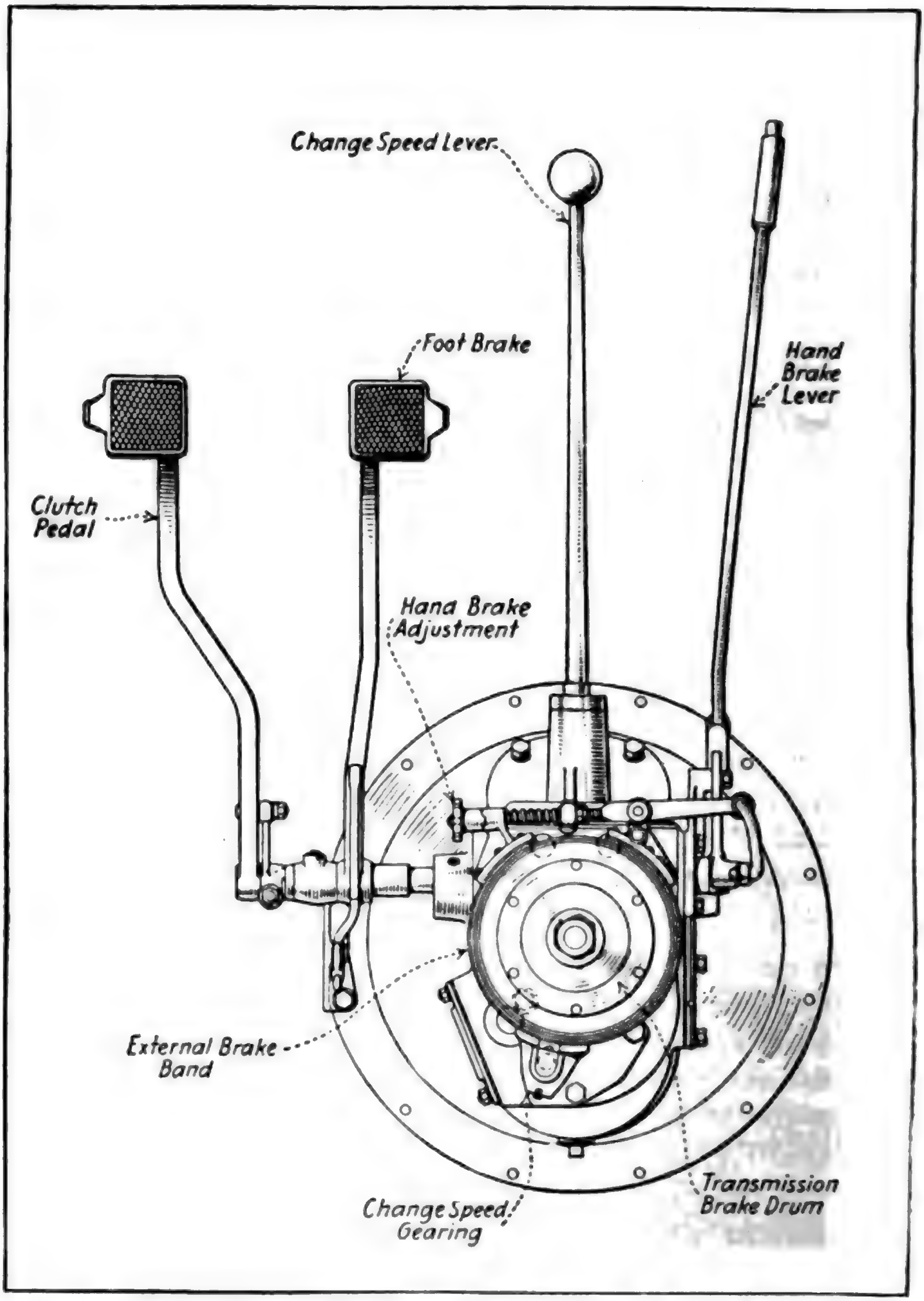

Change Speed Lever
Foot Brake
Hand Brake Lever
Clutch Pedal
Hana Brake Adjustment
External Brake Band
Change Speed Gearing
Transmission Brake Drum

Fig. 449.—The Emergency Brake is Placed on the Rear End of a Unit Power Plant in Numerous Light Trucks.

with both hands and pull directly toward you, being careful not to let the outer bearing slip from the hub and fall to the floor, as this may bend or damage the cage so that the bearing will not render perfect service when replaced. The outer bearing having been removed, lift the wheel off the spindle, exposing the inner bearing.

With a stiff brush and gasoline or kerosene, clean all old grease from both the outer and inner bearings and the inside of the hub. It is not necessary to remove the inner bearing from the spindle in order to do this, although it may be removed if you so desire. In case you do remove the inner bearing, it is sometimes a very good idea to place both inner and outer bearings in a pan containing a mixture of washing soda and hot water, allowing the water to come to the boiling point, which will clean any grease from behind the rollers that the brush and gasoline or kerosene may have failed to remove. If you desire to remove the inner bearing from the spindle care should be taken so as not to bend or damage the cage, which holds the rollers in place on the cone.

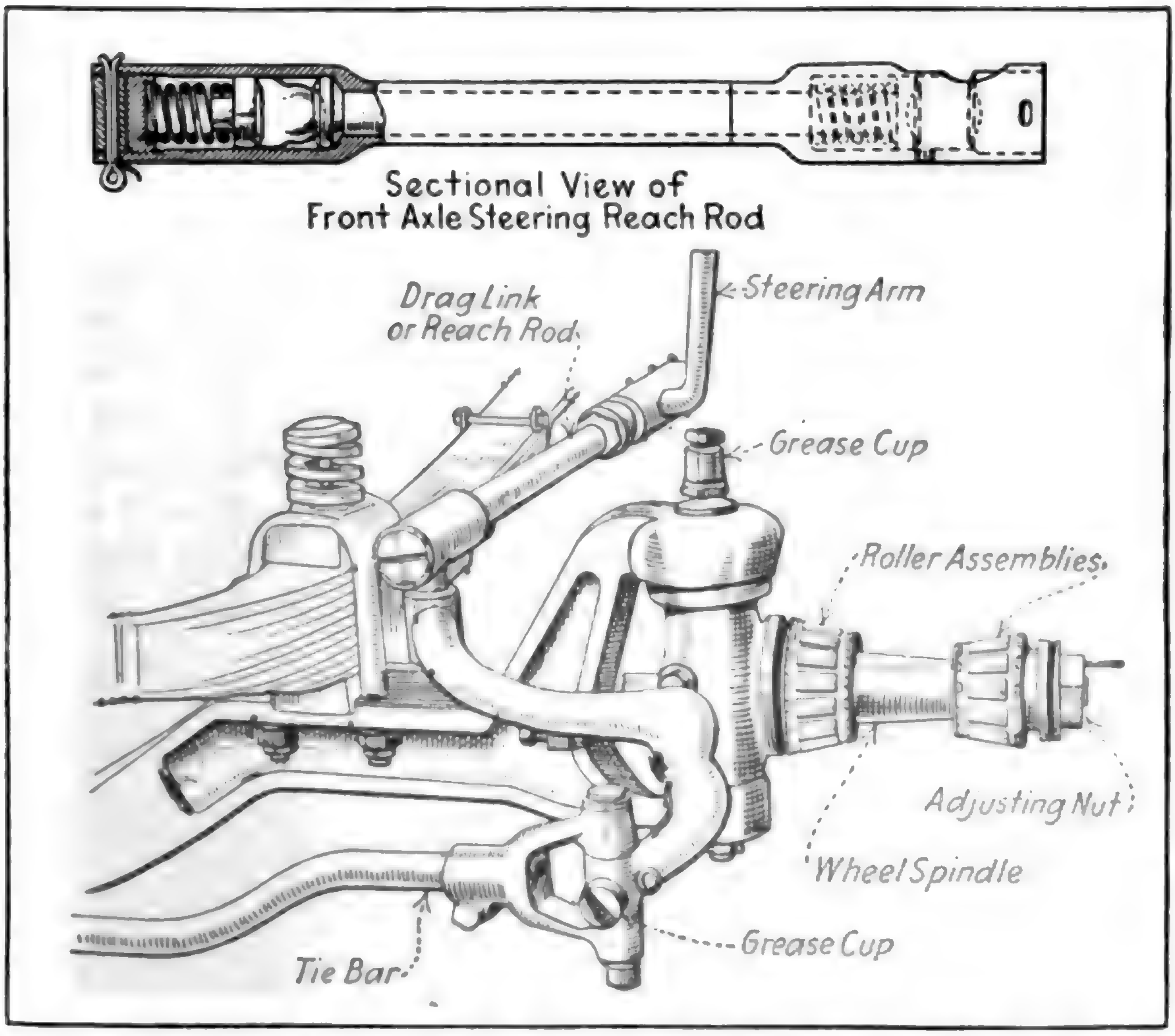

Sectional View of
Front Axle Steering Reach Rod
Drag Link or Reach Rod
Steering Arm
Grease Cup
Roller Assemblies
Adjusting Nut
Wheel Spindle
Grease Cup
Tie Bar

Fig. 450.—Steering Knuckle of Motor Truck Axle Showing Taper Roller Bearings on which Front Wheel Revolves.

The bearings having been thoroughly cleaned and dried, replace the largest, or inner bearing on the spindle, covering it thoroughly with good, clean grease that is free from acid, grit or any solid matter such as fiber. Care should be taken to have no grit or dirt on the paddle. The inside of the hub, itself, should also be thoroughly cleaned, and the space between the two cups, which fit over the bearings and which are pressed firmly into the hub itself, should be repacked with clean grease. To replace the wheel, slide the large or inner bearing on the spindle, pressing it firmly against the flange. Then put wheel on and slide the outer bearing into position. Next screw on the inner lock nut, turning it up tight against the outer bearing. Spin the wheel several times in both directions in order to overcome any tendency to backlash.

Next take a short bar in the right hand and place the end of it between the tire and the floor, at the same time holding the index finger of your left hand on the edge of the outer bearing. Work the bar up and down so that you can detect any excessive play or looseness. When you can feel just a barely perceptible shake and the wheel will oscillate when given a slight spin, your adjustment is right. If there is too much looseness in the bearings tighten up the inner lock nut. If, on the other hand, the lock nut is set too tight to allow the wheel to oscillate, loosen it about one-quarter turn.

Now replace the keyed washer, which goes between the two lock nuts and which prevents the inner lock nut from turning. Replace the outer lock nut and screw up tight; replace the cotter pin in the end of the spindle to eliminate any possibility of the outer nut working loose. Again test your adjustment with the crowbar as before for the following reason:

In using a heavy wrench to tighten the outer lock nut, it is sometimes possible to jam this nut so tightly against the inner nut as to destroy the adjustment. This, however, never happens unless the threads on the spindle have become badly worn. By taking the extra precaution to test the adjustment just before the hub cap is replaced you can be sure that bearings will render service. Cover the end of the spindle and lock nuts with grease, or place a small amount of grease in the hub cap and put the hub cap on, tightening securely.

Rear Wheel Bearings.—The cleaning, adjusting and lubricating of rear wheel bearings is done in exactly the same manner as that described for the front wheels, with the following exception, viz.: There is no hub cap to remove on the rear wheel of some trucks. Instead, you remove the nuts and lock washers from around the hub and pull out the axle shaft, as shown at Fig. 446. Now proceed exactly as you did on the front wheel by removing the outer lock nut, lock washer and inner lock nut. As a rear wheel weighs several hundred pounds, it cannot be lifted off the spindle as easily as a front wheel, hence the following suggestion will be found useful and will also eliminate any necessity for lifting.

After jacking up the rear wheel clear of the ground, take a short piece of board and cover the upper surface with grease; slide this board under the wheel and then lower the jack several notches so that the wheel rests upon the board. Remove outer lock-out lock washer and inner lock-out. The outer bearing can now be removed for cleaning. Be careful, as before, not to let it drop to the floor and bend or damage the cage. The wheel can now be readily eased off the greased surface of the board and rolled to one side. Clean the old grease from the bearings and hub, repack both with fresh grease and replace bearings, wheel and lock nuts as described in the case of the front wheels.

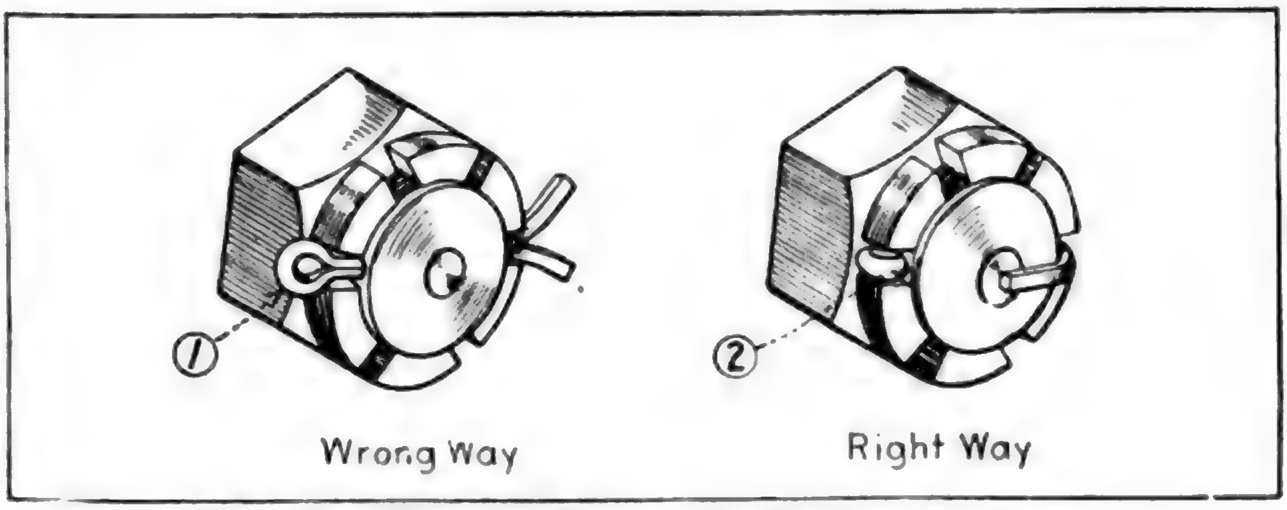


Fig. 451.—Showing How Split Pin Lock is Used.

Even such a simple operation as inserting a split cotter pin may be done incorrectly. The right and wrong methods are shown at Fig. 451. At 1, head of cotter not in slot of nut—turned wrong—nor are the ends split right—turned wrong. This combination will soon work loose and come out. At 2, head of cotter in right—pounded down firm—a snug fit in hole. End of cotter pounded back over end of bolt—other end pounded down. Cotter should be tight and stay so.

Steering Gear Care and Adjustment.—The steering gear should receive some attention. There are four classes of steering gears in common practice. The steering gear used in Ford

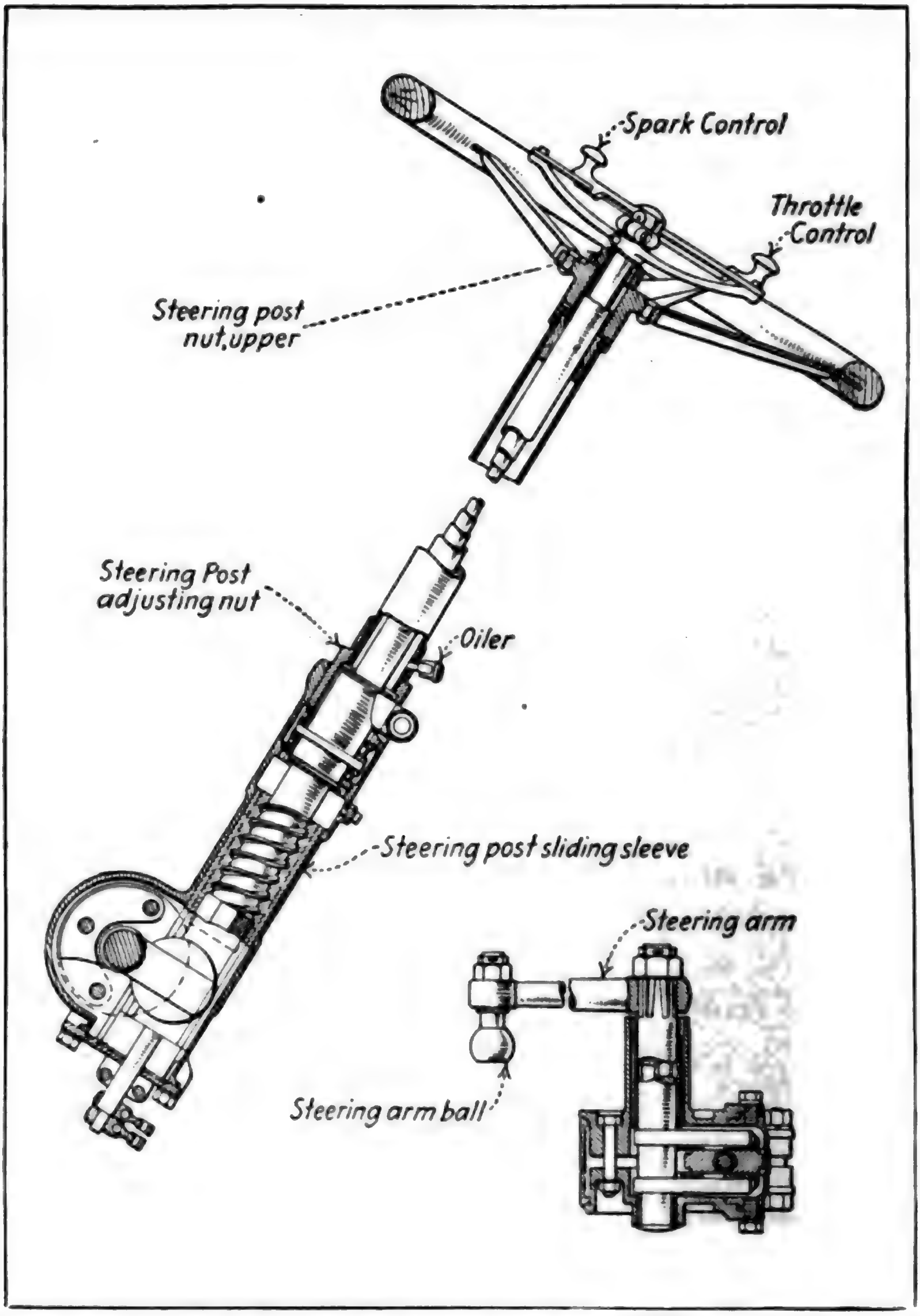

Spark Control
Throttle Control
Steering post nut, upper
Steering Post adjusting nut
Oiler
Steering post sliding sleeve
Steering arm
Steering arm ball

Fig. 452.—Typical Example of Worm and Nut Type Steering Gear for Motor Truck Use.

trucks has the gears arranged in the "sun and planet" form on the steering post just beneath the wheel. Take off the steering wheel by loosening the brass nut on top and with a mallet and a block of wood drive off the wheel. Just below on the post will be seen the small case that holds the gears. Remove screw that holds cover and the cover can be removed. The gears may then be inspected, new gears may be put in if necessary and the gears packed with grease. Then replace the cover and screw, put the wheel back in place and set up the nut that holds it. At the lower end of the steering post on Ford cars look for play in the ball joint and socket. If play is found the joint may be taken apart and the cap smoothed down with a file so it will fit the ball more closely. If the ball is worn too much replace it with a new arm. The ball socket on the other end of the rod fastened to this ball should be examined and treated in the same manner. The bushings in the ends of the tie rod can sometimes be tightened to take out the play or replaced with new ones or the holes may be reamed out a size larger and a large bolt put in. The front wheels should be adjusted for end play by means of the adjusting cone on the end. Fill the hub caps with grease and screw them in place. This will supply the front wheel bearings with the necessary grease for about 500 miles.

Another steering gear is the bevel rack and pinion type used on Reo trucks. The lower end of the post carries a small pinion that meshes into a rack or half gear supported at the center by a short shaft that passes out through the frame to the steering arm. The adjustment is secured by means of an adjusting screw in the bracket at the side of the rack. Loosening the set screw that holds the adjusting screw allows the adjusting screw to be turned either in or out, forcing the rack deeper into mesh with the pinion or drawing it out of mesh. The face of these gears should be kept lubricated for silent operation. A grease cup on the steering post feeds the shaft inside just back of the pinion. This needs attention occasionally.

The Worm and Nut Types.—The worm and nut type steering gear is used to some extent. Here the steering wheel is carried on a long tube, the lower end of which carries a double threaded worm or screw, engaging with two half nuts which slide up and down in guides in the steering gear housing. The threads on the steering screw are right and left hand. One of the nuts has a right-hand thread and the other a left-hand thread. When the steering wheel is turned, one of the nuts rises on its guide, while the other is forced down. At their lower ends the half nuts carry hardened steel thrust blocks which push against rollers attached to the steering yoke and by their motion the

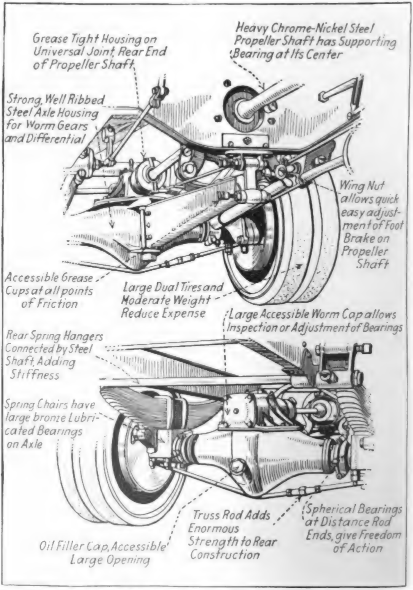

Grease Tight Housing on Universal Joint, Rear End of Propeller Shaft
Heavy Chrome-Nickel Steel Propeller Shaft has Supporting Bearing at Its Center
Strong, Well Ribbed Steel Axle Housing for Worm Gears and Differential
Wing Nut allows quick easy adjustment of Foot Brake on Propeller Shaft
Accessible Grease Cups at all points of Friction
Large Dual Tires and Moderate Weight Reduce Expense
Large Accessible Worm Cap allows Inspection or Adjustment of Bearings
Rear Spring Hangers Connected by Steel Shaft, Adding Stiffness
Spring Chairs have large bronze Lubricated Bearings on Axle
Truss Rod Adds Enormous Strength to Rear Construction
Spherical Bearings at Distance Rod Ends, give Freedom of Action
Oil Filler Cap, Accessible Large Opening

Fig. 453.—Radius Rods, Spring Shackles and Other Parts at the Rear of a Chassis. Illustrations Also Show Good Features of Modern Truck Axle.

yoke is tilted in the housing, moving the steering arm backward and forward. Owing to the liberal wearing surfaces provided, there is but little depreciation of the mechanism.

Adjustment is made by means of an adjusting ring at the top of the worm. Loosen the clamp that holds the ring to the post tube and with a large wrench turn the ring to the right to tighten or to the left to loosen. About one-half inch oscillation should be allowed at the wheel. Lubrication may be supplied by means of a grease cup on the worm housing. Keep this filled and turn down a couple of turns every two or three days.

The traveling nut working up and down on the screw in the I. H. C. steering gear carries two slotted rotating pieces, in the slots of which slide the rectangular arms of the rock shaft, to the outer end of which the ball lever is attached; all is clearly shown in illustration, Fig. 452. The case is packed with grease when assembled and should work a year without needing attention. An oiler is provided at the upper end of the case, through which oil can be inserted in case of emergency. The ball joints in the fore and aft drag link should have the leather boots removed about every 2,000 miles for cleaning and repacking with grease.

The fourth type and the most common one is that known as the worm and sector. In this construction we have the same method as used in the worm gear system drive; that is, the worm meshes into a gear with the teeth cut to match the spiral of the worm but the motion is an oscillating one only. Adjustment for the up and down motion of the worm is cared for at the bottom of the steering post, while the adjustment of the worm gear is cared for at the outer end of the shaft that the gear is carried on. Here a bushing is found that will take out any play that may develop. The nuts and bolts on these adjustments must always be kept tight. Grease cups on the steering gear housing should be kept filled and turned down. Sometimes an eccentric bushing is used to support the worm gear shaft, and by this means the gear may be brought closer in mesh with the worms on the steering column. A large variety of steering gears of all types are shown in a previous chapter dealing with running gear parts.

Chassis Repairs.—Even after the power plant and gearset have received attention, there are numerous points about the chassis of the truck that should be inspected if a thorough overhauling is called for. The chassis of any well-built car will need but very little attention if the various parts are well oiled until it has been used from ten to fifteen thousand miles. After this distance has been covered, the motorists will probably be

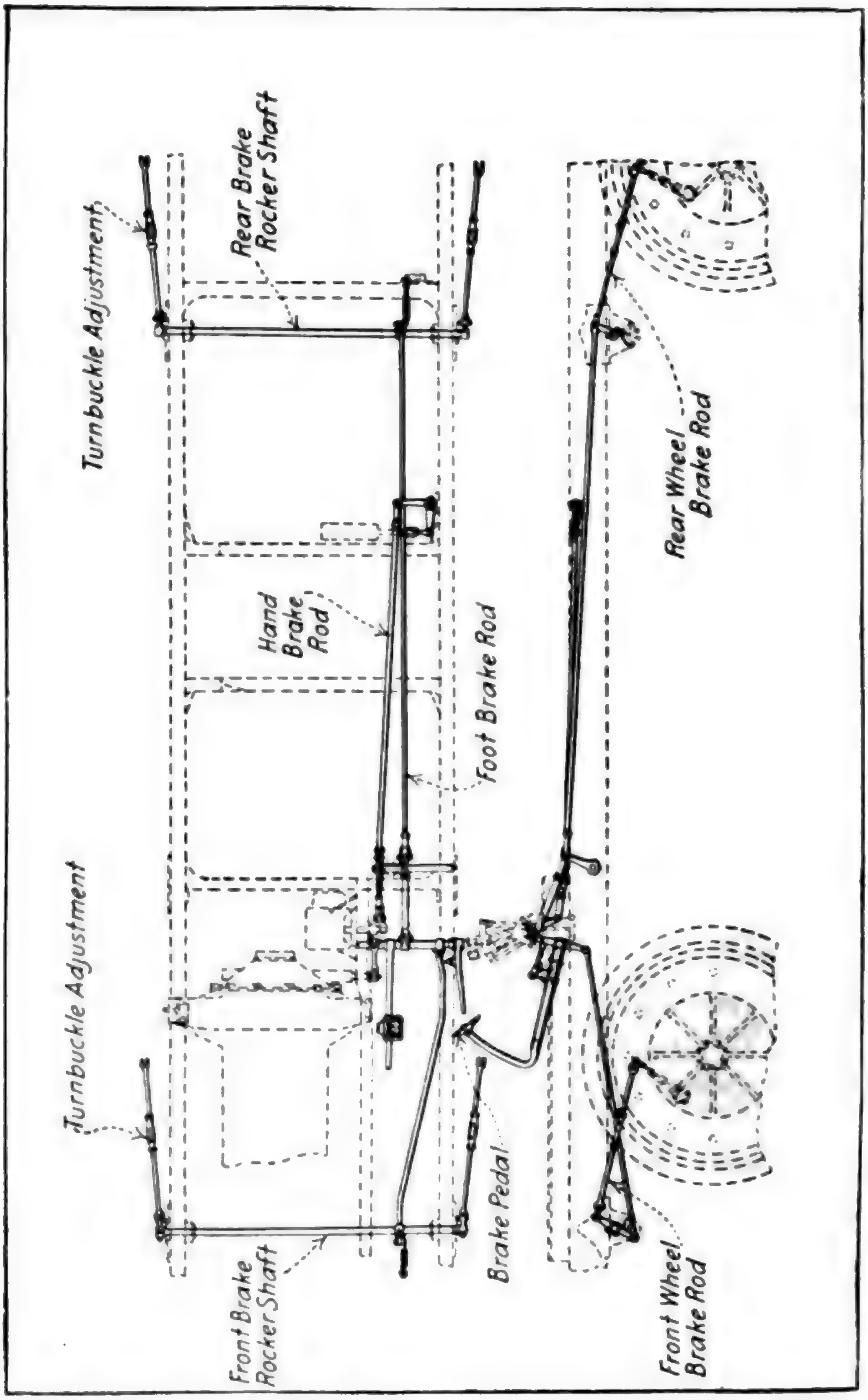

Turnbuckle Adjustment
Rear Brake Rocker Shaft
Hand Brake Rod
Foot Brake Rod
Rear Wheel Brake Rod
Turnbuckle Adjustment
Brake Pedal
Front Brake Rocker Shaft
Front Wheel Brake Rod

Fig. 454.—Brake Linkage of Nash Quad Truck Needed to Operate Brakes on all Four Wheels.

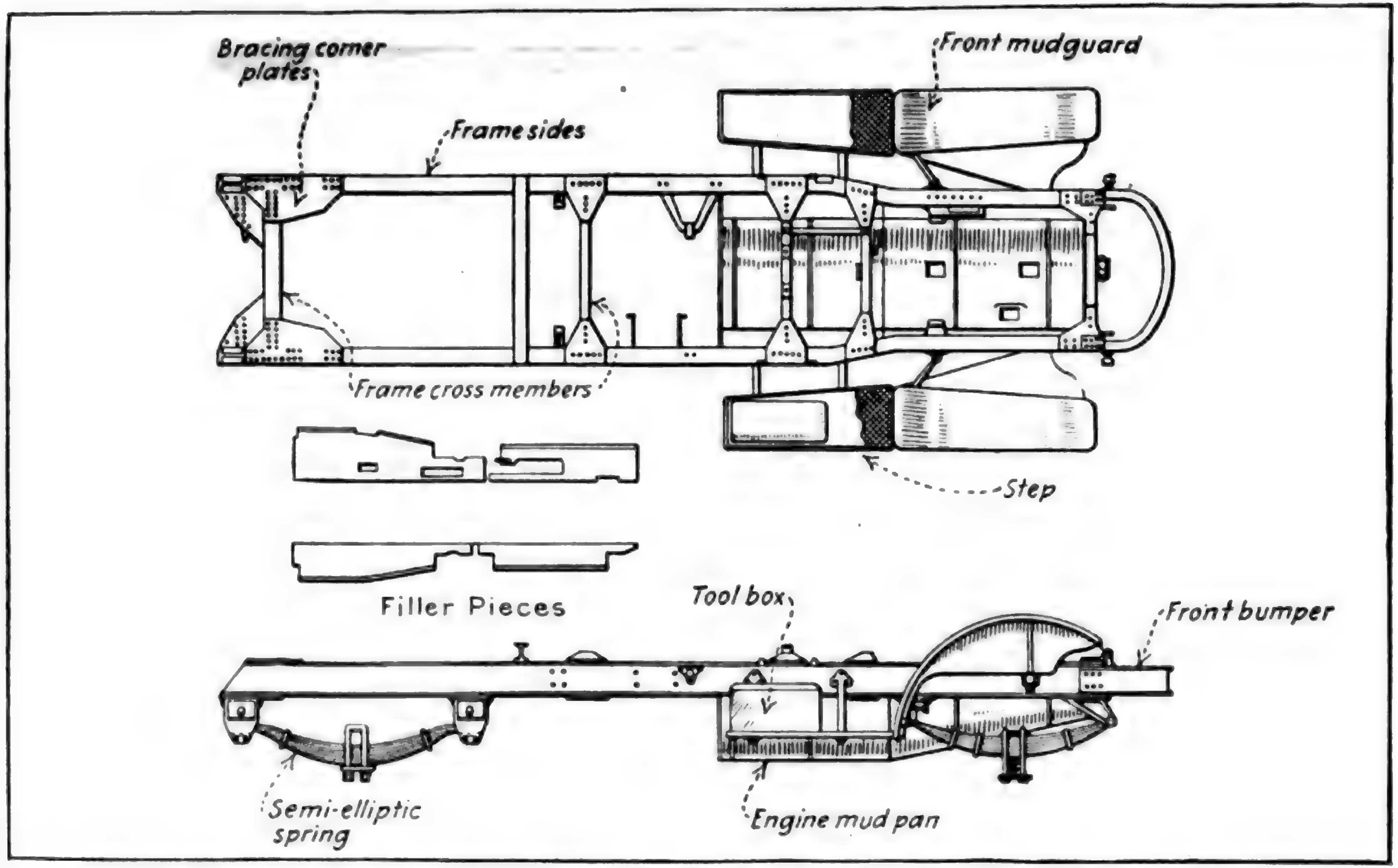

Bracing corner plates
Frame sides
Front mudguard
Frame cross members
Step
Filler Pieces
Tool box
Front bumper
Semi-elliptic spring
Engine mud pan

Fig. 455.—Frame of Large White Trucks Showing Parts Needing Inspection.

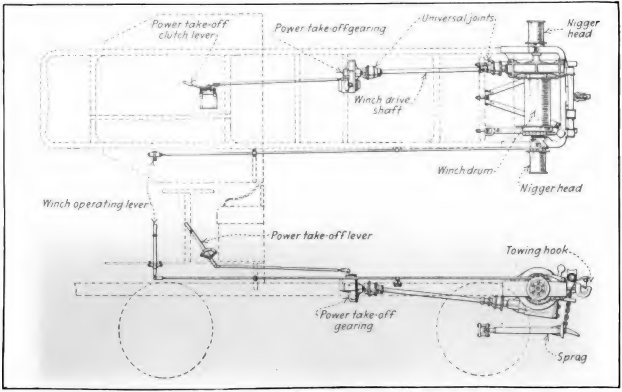

Power take-off clutch lever
Power take-off gearing
Universal joints
Nigger head
Winch drive shaft
Winch drum
Nigger head
Winch operating lever
Power take-off lever
Towing hook
Power take-off gearing
Sprag

Fig. 456.—How Power Operated Winch is Installed on Frame of Motor Truck.

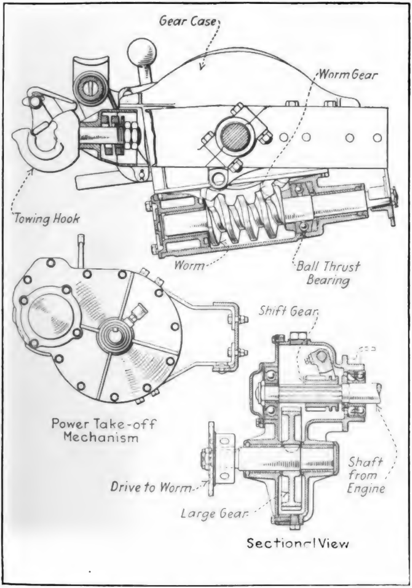

Gear Case
Worm Gear
Towing Hook
Worm
Ball Thrust Bearing
Shift Gear
Power Take-off Mechanism
Shaft from Engine
Drive to Worm
Large Gear
Sectional View

Fig. 457.—Power Take-off and Worm Drive for Truck Winch.

annoyed by a series of squeaks and rattles, even though the engine and gearset are in perfect running condition. These rattling noises indicate wear at a number of relatively unimportant bearing points, and even though the depreciation is slight, the looseness at the multiplicity of small joints will produce a noise that

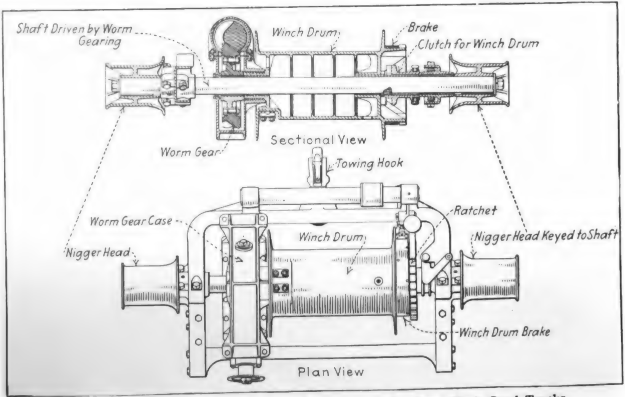

Shaft Driven by Worm Gearing
Winch Drum
Brake
Clutch for Winch Drum
Sectional View
Worm Gear
Towing Hook
Ratchet
Worm Gear Case
Winch Drum
Nigger Head Keyed to Shaft
Nigger Head
Winch Drum Brake
Plan View

Fig. 458.—Winch Drum Mechanism Used on Some of the Army Nash Quad Trucks.

will be unmistakable whenever the car is operated on other than perfectly smooth highways. Among some of the things to be looked for are wear in the various control linkage members, sagging or bent frame side members, loose cross members or gusset plates, due to rivets having loosened up in service; stiff action of the springs, due to rust accumulating between the leaves; looseness in the steering gear and steering connections, lack of alignment of the front and rear wheels, looseness of the wheel hub bearings, and numerous other conditions that have been enumerated and discussed in this chapter.

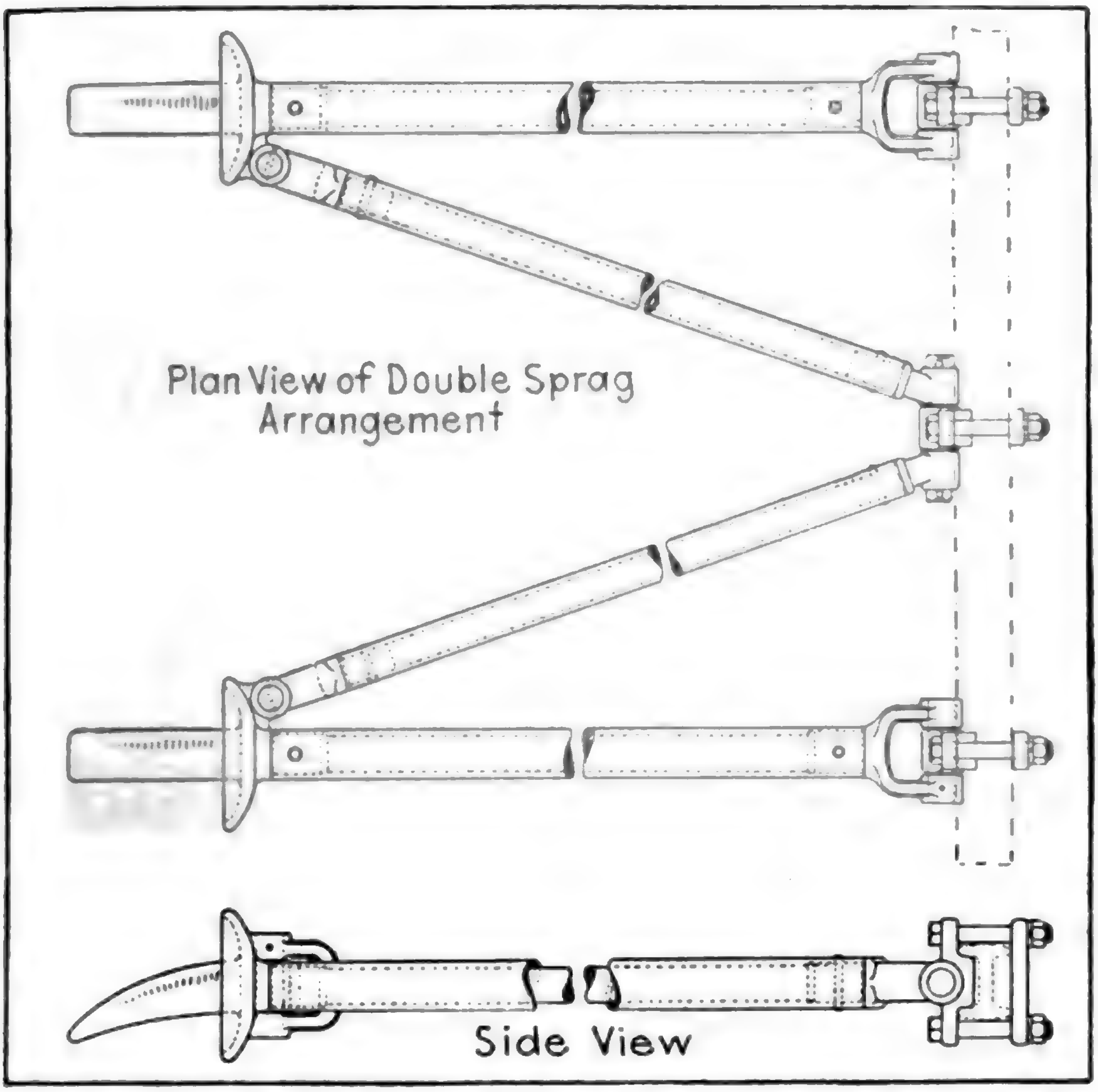


Fig. 459.—Double Sprag Arrangement Used with Truck Equipped with Winch at Rear of Frame.

It is not unusual to find the rivets at the corners of a frame or those holding cross members and gussets or reinforcing plates loose. If they are not very loose, satisfactory repairs can often be made by peening them over again, using a heavy hammer and a suitable anvil or rivet set to receive the force of the hammer blow. A rivet set for frame work may be easily made by taking a large bar of square or round section iron or steel, three feet long and two inches in diameter, and turning up one end at right angles to the bar about three or four inches back from the end. Both ends are then tapered down so that the area is approximately an inch square. A suitable countersunk depression is then made to receive the rivet head at each end of the bar; one may also be placed on the side of the bar about an inch from the end. This will permit the use of the same bar in corners as well as on rivets so placed that the length of the bar does not prevent it being held against the rivet heads. Two men are required to do a good job of riveting, one to manipulate the riveting hammer, the other to hold the bar up against the rivet and absorb the impact of the hammer. If the frame members are very loose it indicates that the rivets have become reduced in diameter and partially sheared. In cases of this kind nothing will be gained by peening the rivet heads over more. The only safe remedy is to chip off the rivet heads with a sharp cold

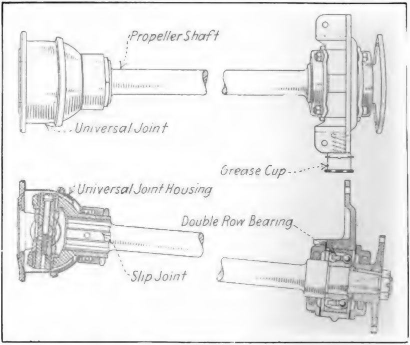


Fig. 460.—Driving Shaft and Universal Joints of Winch Drive Mechanism.

chisel and then knock them out of the holes with a steel drift. The holes are then drilled to the next larger standard rivet size and new rivets secured. These are usually of Norway iron, and should be heated to a red heat in a gas or coal forge before being headed up.

The frame side members sometimes sag after the car has been used for a period, especially if it is operated at high speeds over rough roads, or in the case of a motor truck that has been made to carry overloads. A weak channel section member of this character can be made stronger by either of two methods. It may be reinforced by a plate riveted to the interior or it may be trussed by truss bar and turnbuckle arrangement. Sometimes a plate is added to both inside and outside of the frame and the whole held together by rivets or bolts.

Muffler Should be Taken Apart.—A part of the chassis that is often overlooked in the overhauling and one that has material influence on the power output of the motor is the device used for muffling the sound of the exhaust. The internal construction of mufflers varies widely, some consisting only of simple chambers connected together to form a labyrinth for the gas passage and reduce the noise by breaking up the volume and allowing the gas to expand before it reaches the air, to more complicated forms having a large number of baffle plates or partition walls pierced with numerous small holes. The most effective and silent type of muffler is generally the one that will give trouble first. It is important, therefore, to take the muffler apart and clean out all accumulations of soot or burnt oil that may clog up the gas passages. Mufflers are easily taken apart, usually being held together by long through bolts in those forms where the muffler consists of a number of cylindrical shells of varying diameter held between cast end plates used to support the shell. Even in forms where a large number of chambers are provided, these being adjacent, the muffler is held together by bolts or by being assembled on a central member, usually a continuation of the exhaust pipe. After the muffler is taken apart all carbon and burnt oil residue should be scraped off and all the parts of the muffler thoroughly cleaned with kerosene before assembling. It is also well to go over all the holes designed to break up the gas with a sharp punch or fine taper reamer to make sure that these have not been reduced to less diameter than they should be by accumulations of burnt oil or carbon.

CHAPTER XIII

THE ELECTRIC TRUCK CONSTRUCTION

Features of Electric Trucks—The Couple-Gear Construction—Features of Couple-Gear Gas Electric—Commercial Electric Trucks—Elimination of the Differential Gear—Rear Construction of Commercial Trucks—Four Wheel Drive Advantages—Motor Wheel Assembly. Internal Gear Drive—Battery Compartment Location—Proportions of Battery Compartment—Controller of Commercial Trucks—Commercial Truck Specifications—Walker Balanced Drive Truck—Batteries for Electric Trucks—Motors for Electric Automobiles—Electric Vehicle Controllers — General Electric Controllers — General Electric Continuous Torque Controller—Controller Wiring Diagram—Resistance Grids—Connections—Westinghouse Vehicle Motors—Westinghouse Vehicle Motor Performance—General Electric Vehicle Motors—Magnet Frame-Bearing Head and Bearings—General Electric Commutators and Brush Holders—Connections—Truck Motors and Battery Arrangement—Faults in Motors and Their Corrections—Electrical Terms Defined—The Volt—The Ohm—The Ampere—The Watt.

Electric trucks have many parts in common with gasoline trucks as relates to the frame and running gear components, but instead of a gasoline motor and its auxiliaries, a clutch and change speed gearing, the power plant is simplified to a large storage battery and one or more electric motors. The control of the electric truck is different, as, while the steering gear is practically the same as on the gas truck, there is no clutch pedal or gear-shifting lever. The motor speed is varied through a controller which couples the motor windings and storage batteries in various combinations, to be explained later, which will give high power at low motor speed or increase the speed without increasing the motor power.

In some forms, the motor is carried by the frame and power is transmitted from the armature shaft to a rear axle of the type ordinarily used on gasoline trucks by a universally jointed propeller shaft. This one motor construction is not only found on trucks of light capacity, as the Ward one-ton job shown at Fig. 461, but also on trucks of larger capacity, as in the Landsen five-ton shown at Fig. 462. In this, a single motor is attached to a jackshaft, which in turn transmits the power to the rear wheels by chain connection, just as in a double chain drive gasoline truck. In other trucks one motor is attached to the center of the rear axle, as in the Walker one motor may be used to drive each rear wheel, as in the Commercial Truck Co. models, or in all four wheels, as in the Couple Gear trucks, one model of which is shown at Fig. 462. The battery location is the same

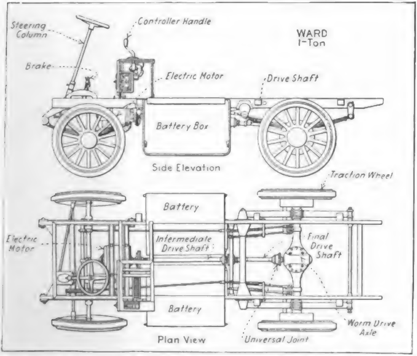

Steering Column
Controller Handle
WARD
1-Ton
Brake
Electric Motor
Drive Shaft
Battery Box
Side Elevation
Traction Wheel
Battery
Electric Motor
Intermediate Drive Shaft
Final Drive Shaft
Battery
Worm Drive Axle
Plan View
Universal Joint

Fig. 461.—Diagrams Showing Construction of Ward 1-Ton Electric Truck.

on nearly all trucks, i.e., underslung at the frame center between front and rear axles.

Features of Electric Trucks.—First: Extremes of weather have no effect on the mechanism either from overheating in the summer or danger of freezing in the winter, though the battery capacity is reduced in cold weather. Second: An electric truck may be garaged in any type of building and can be used in warehouses or in docks and around all factories or yards where fire prevention regulations prohibit the gasoline truck. Third: In the transporting of ice, produce, munitions or other similar type

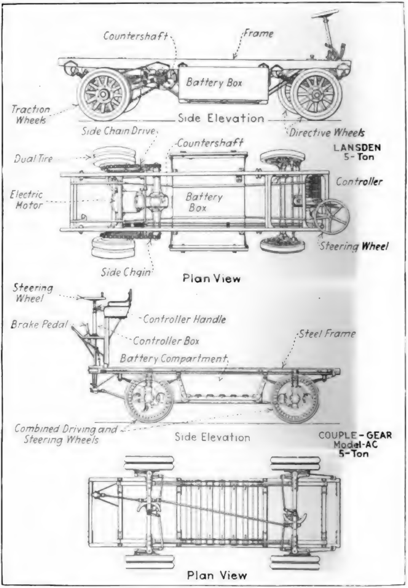

Countershaft
Frame
Battery Box
Traction Wheels
Side Elevation
Side Chain Drive
Countershaft
Directive Wheels
LANSDEN
5-Ton
Dual Tire
Controller
Electric Motor
Battery Box
Steering Wheel
Side Chain
Plan View
Steering Wheel
Brake Pedal
Controller Handle
Controller Box
Steel Frame
Battery Compartment
Combined Driving and Steering Wheels
Side Elevation
COUPLE-GEAR
Model-AC
5-Ton
Plan View

Fig. 462.—Typical Large Capacity Electric Motor Trucks.

of merchandise it is imperative that there shall be no excess heat or odor, and in case of explosives the fire hazard from explosions in mufflers or backfiring is extremely dangerous. For this class of work the electric truck surpasses all other forms of transportation. Fourth: It is claimed that trained horse wagon drivers may be converted into excellent electric truck drivers in a day. Women are driving electric trucks in many parts of the world.

The Couple-Gear Construction.—Couple-gear vehicles are supplied with one or more driving wheels, as may be required to

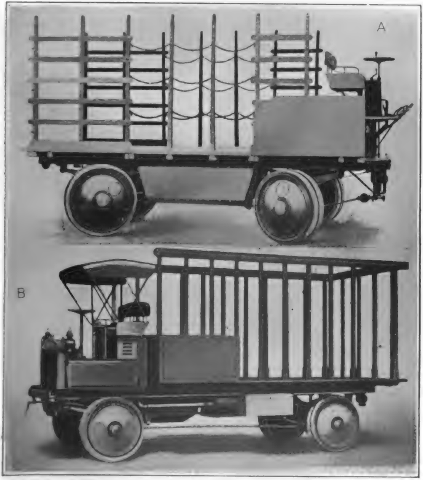


Fig. 463.—Couple Gear Straight Electric Truck Shown at A. Combination Gas-Electric Truck Shown at B.

easily handle the desired loads. Load capacities range from one to fifteen tons. The following advantages are advanced for this construction, which is to be described in detail, by the manufacturers, the Couple Gear Freight Wheel Co., Grand Rapids, Mich. Two forms of these trucks are shown at Fig. 463. That at A is the four-wheel drive and steer straight electric drive; that at B is the gas-electric form. The following features are claimed by the manufacturers:

A higher transmission efficiency than has ever before been possible. Four-wheel drive is easily and naturally accomplished with the Couple-gear, because the motor, driving gears and wheel are one complete unit and can be turned at any angle for steering without interfering with most efficient operation. Steering from the four wheels is also a natural result of the Couple-gear motor wheel construction, because the added parts to bring it about are few and simple. This makes it possible to steer the car equally as well in either direction, and effecting a considerable saving on rubber tires and their fastenings by relieving side strains in turning corners and because of the fact that skidding is practically avoided. Brakes on all four wheels are a natural

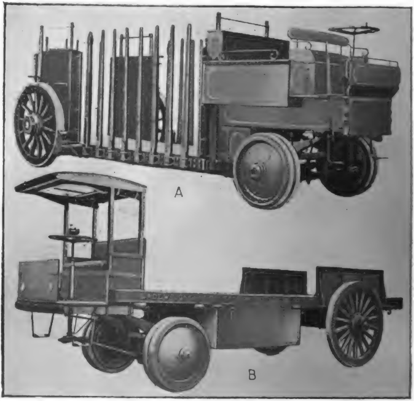


Fig. 464.—Couple-Gear Front Drive Trucks Permit Using Bodies that Could Not Be Employed on Gasoline Trucks.

sequence of driving and steering from the four wheels and greatly lessens the danger of accident. Four Motor Control gives five speeds forward and five speeds reverse with the most efficient series-parallel arrangement. Couple-Gear machines all develop the highest speeds compatible with safe and economical operation. Motors and driving gears are in the most accessible position possible, and are conveniently inspected and oiled through doors in the wheel's sides, which fit dust and water-tight. Motor-wheels are interchangeable, as are also all parts of which they are composed. A sufficient gear reduction, due to the "Couple-gear" arrangement, to enable the car to start easily without causing a heavy rush of current and also to enable the car to operate sufficiently slow to pull through deep sand, snow or mud without overloading the motors beyond a safe and practical limit. This insures long life for all electrical parts. Hauling trailers is practical and is a common practice with Couple-Gear Four-Wheel-Drive Trucks. In this way the possible load on a single trip is double and sometimes triple the normal capacity of the machine. Four-wheel steering adds to the convenience of the machine as a tractor. (Couple-Gear Five-Ton Trucks are sometimes used to great advantage for switching railway freight cars and have been sold for this special purpose.)

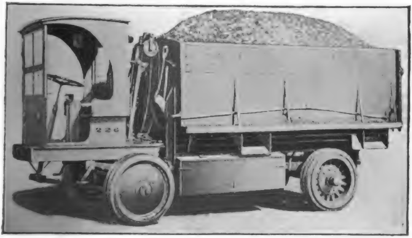


Fig. 465.—Couple-Gear Front Drive Truck with Dumping Type Body.

The use of Couple-Gear front driving sets enables the operator to use the type of after-construction best suited to his needs.

The "low-down" type of wagon shown at Fig. 464, A, is especially desirable in the western and southern districts, and are giving results that are most pleasing. Then again special body types may be easily fitted, as shown at Fig. 464, B, and Fig. 465.

Features of Couple-Gear Gas-Electric.—The Gas-Electric has no starting clutch, no long shafts or countershafts with their bearings, no change speed gears, no differential gear, no sprockets or chains or live rear axle with its friction surfaces. The functions of all these parts are performed in the Gas-Electric by the generator, wiring, driving motors and "Couple-gear." The total efficiency, including the electrical losses, averages higher than it is possible to secure by the best design of mechanical transmission for this class of work, while the mechanical losses, aside from those of the engine, are nearly all eliminated. Mechanical losses are represented by wear of mechanical parts, while electrical losses are all dissipated in heat at low temperatures and cause no wear or depreciation whatever. The range of speed is from zero to full, with a perfect graduation, and the car can be operated efficiently and continuously at the speed best suited to the immediate road and load conditions. Also, the engine can be run at the best speed for the work which it is performing, regardless of the speed of the car, and this desirable condition is largely automatic. The ample leverage of the "Couple-Gear" makes starting easy, and consequently it is never necessary to race the engine. The acceleration is very rapid and

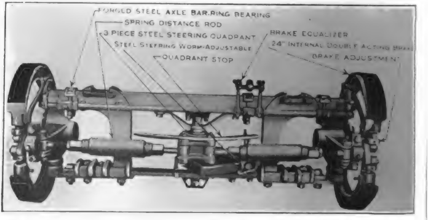

FORGED STEEL AXLE BAR.RING BEARING
SPRING DISTANCE ROD
3 PIECE STEEL STEERING QUADRANT
STEEL STEERING WORM-ADJUSTABLE
QUADRANT STOP
BRAKE EQUALIZER
24" INTERNAL DOUBLE ACTING BRA
BRAKE ADJUSTMENT

Fig. 466.—Special Axle Construction Used on Couple-Gear Trucks.

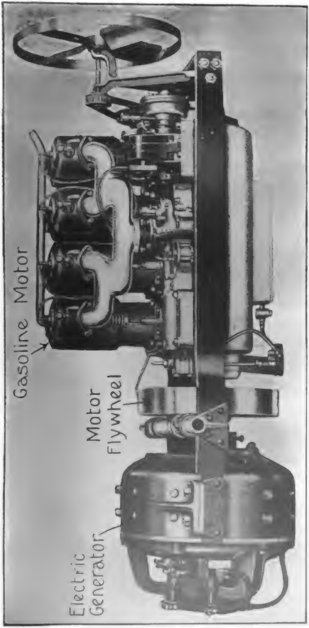

Electric Generator
Motor Flywheel
Gasoline Motor

Fig. 467—Power Plant of the Couple-Gear Combination Gasoline-Electric Drive Trucks.

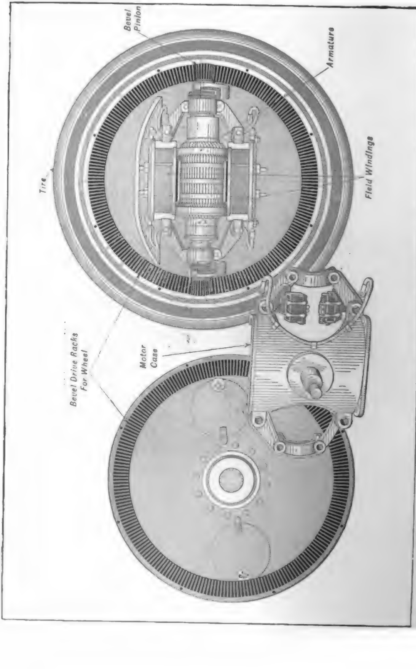

Bevel Pinion
Armature
Tire
Field Windings
Bevel Drive Racks For Wheel
Motor Case

Fig. 468.—Outlining Construction of the Wheel Used in Couple-Gear Vehicles. Note the Location of the Driving Motor in the Center of the Wheel and Method of Driving.

absolutely smooth. There are no sudden shocks whatever, either in starting or changing from one speed to another, and because of this fact there is a substantial saving in the maintenance of the engine and every part of the machine.

Combination Gasoline-Electric Drive.—One of the great advantages of the electric automobile outside of its silence and smooth operation is the ease with which the speed and power may be controlled. On the true gasoline type it is necessary to shift gears in order to obtain various speed changes, and unless this gear shifting is very carefully done it may be possible to damage the transmission and also to impose shocks on the entire mechanical structure, due to too sudden engagement of driving gearing or clutches. While this defect is not serious enough to be a disadvantage of moment, at the same time it is evident that the operator of a gasoline car must be very competent and thoroughly familiar with the manipulation of the speed-changing and clutch-control levers. The various speeds in an electric truck are obtained by a simple movement of a controller handle, without shock or jar, because electric current is used for propulsion. This makes it possible for ordinary drivers to control the vehicle, because it does not require any special skill to move the controller handle, whereas it does take practice and experience to properly manipulate a sliding gear transmission and clutch.

There are some disadvantages to the application of electric power alone, and it seems to be the general opinion of engineers all over this country and in Europe that gas power is more suited for commercial work than is electric power, if the latter is derived solely from storage batteries. An electric vehicle depending upon stored energy is not capable of the speed that can be made with a gasoline engine as a power plant. The range or radius of action of the average electric battery is apt to be somewhat limited, and one might easily imagine a condition, especially in a city or town of any size, where enough distance might be covered in the course of a day to prevent proper charging of the storage battery, and this, of course, would result in diminished efficiency as the battery charge became depleted. The writer does not mean to imply that electric power derived from a storage battery is impractical. On the contrary, many very efficient motor trucks are propelled by this power.

An ideal combination in which the main advantages of both gas and electric power are obtained is the combination of gasoline-electric system in which the prime mover is a gasoline motor which delivers its power to an electric generator instead of to the usual form of gear transmission. With this combination one is obliged to obtain a large radius of action, inasmuch as the gasoline engine may be operated continuously as long as the supply of gasoline and oil is adequate, and by the use of the electric power to turn the wheels one is enabled to gain the main advantages, namely, easy control and simplicity of operation, that would be obtained in electric automobiles.

The Couple-Gear system is a well-known method of utilizing electricity as a means of speed changing and power transmission with a gasoline engine as a prime mover that supplies electrical energy by driving a dynamo attached directly to the crankshaft. The general arrangement of parts of the power plant is depicted at Fig. 467. The gasoline engine and the dynamo it drives are attached to a subframe member, so the power plant complete is a unit that may be readily installed on the main frame of the chassis.

The distinctive feature of the Couple-Gear system is the method of mounting the wheel-driving motors between the two members comprising the wheel. One motor is attached inside of each driving wheel, as shown at Fig. 468. The motor frame is attached to a carrier member integral with the wheel spindle and drives the wheel through two beveled pinions at the ends of the armature shaft, one of which meshes with a bevel drive circular rack or driving gear at one side of the wheel, while the other pinion engages a gear of corresponding size on the other side of the wheel. At Fig. 468 one side of the wheel is taken off so the construction of the wheel-driving motor and the arrangement of the driving gearing may be readily ascertained. The illustration, Fig. 469, shows a front view of the wheel with the rim removed to show the manner in which bevel pinion A drives bevel rack A, while the bevel pinion B is in mesh with the bevel rack B. The wheel spindle which projects from one side of the wheel fits a corresponding taper hole in a steering knuckle of suitable form, which makes it possible to incline the wheel as desired for steering without interrupting the continuity of the drive. The Couple-Gear system is sold in two- and four-wheel units, and where four wheels are used, all four members combine directive and tractive functions. The two-wheel type is in the nature of a tractor that is intended to be attached to the front portion of the frame of any heavy vehicle, such as fire apparatus.

The Couple-Gear system is well adapted to fire apparatus, as shown at Fig. 470, because it can be fitted to existing forms of horse-drawn equipment, as shown at A, which shows a Couple-Gear tractor fitted to a steam fire engine. The illustration at B shows an aerial truck similarly equipped. A special form of turntable and hoist is used to raise and lower the ladder and

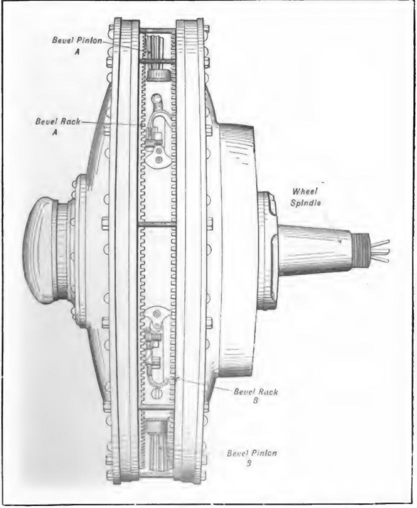


Fig. 469.—Front View of the Couple-Gear Wheel, with Tire and Rim Removed to Show Method of Driving by Bevel Pinions and Racks.

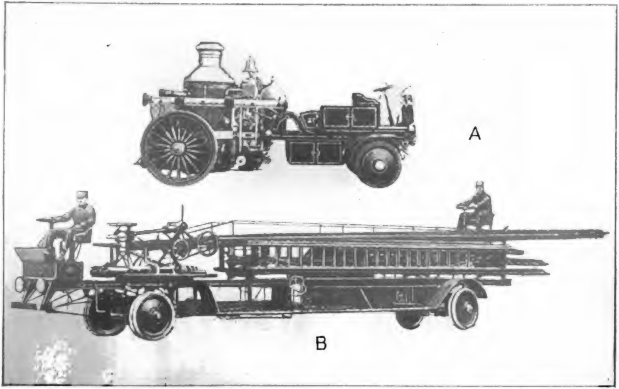


Fig. 470.—Showing How Couple-Gear Front Drive Equipment Can Be Used Advantageously with Fire Apparatus Formerly Horse-drawn.

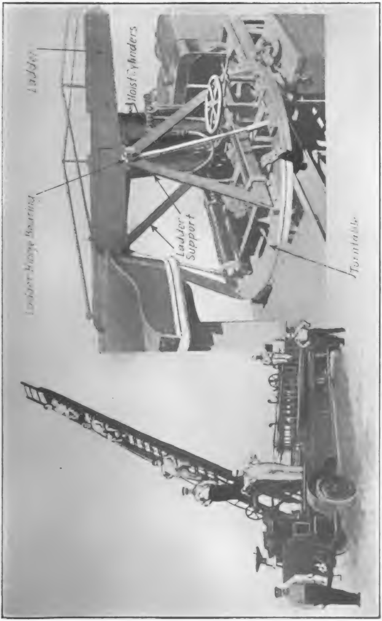

Ladder
Hoist Cylinders
Ladder Hinge Bearing
Ladder Support
Turntable

Fig. 471.—Couple-Gear Driven Aerial Truck with Special Ladder Raising Mechanism.

also turn it around as needed. The construction of this equipment is shown at Fig. 471. The turntable is of standard type. The circles are forged and turned from high carbon steel; the upper ring is carried on seven-eighths-inch steel balls. The hoist is the Dahill compressed air type, liquid controlled, and consists of three seven-inch cylinders with pistons and rods. These cylinders are connected by trunnion to the turntable and have free oscillating movement. The outer end of piston rods are connected by trunnion to the main ladder. Opening one valve permits compressed air to flow freely into the bottom of the two outer cylinders. The center cylinder is filled with oil and equipped with bipass and air chamber in combination. The opening given the valve in the bipass piping regulates the speed at which the ladder is elevated. The check valve in bipass line automatically locks the ladder in position when the air is cut off. Air tank and motor driven compressor are carried at rear of chassis frame. One man using only one hand raises and lowers the ladder at will.

Commercial Electric Trucks.—The electric trucks made by the Commercial Truck Company of America are of the two-motor drive type, for which they claim the following advantages: The two-motor drive permits of a series parallel control which eliminates a large part of the resistance necessary where a single-motor drive is used. This results in considerably less waste of current when accelerating the vehicle. In addition, the two-motor equipment permits of a system of control that provides for running the motors in series, and results in a very efficient low speed running point, which is most advantageous in congested streets, whereas with the single-motor drive it is necessary to waste power through resistance when traveling at low speed. The two-motor equipment also permits of the very efficient type of spur gear drive illustrated, which is not possible with a single-motor equipment. The above features are said to result in greater mileage with the same battery capacity.

Elimination of the Differential Gear.—In addition to the fact that the elimination of the differential gear makes a much simpler construction, there is the decided advantage, especially under winter conditions, of better traction. With the single-motor drive with differential gear the traction that can be exerted by either wheel is limited to the amount that the wheel with the poorest adhesion can exert without slipping, whereas, with the two-motor drive, each wheel is a separate and independent power unit, and if one wheel has good traction it will exert its full effort, although the other wheel may be slipping.

The spur gear is undoubtedly the most reliable, most efficient and most durable form of speed-reducing device, where conditions are favorable for its use and where they are properly mounted, lubricated and protected from grit, all of which features —and some additional features of value—have been properly taken care of in the driving mechanism of these trucks, as will be evident from the following description:

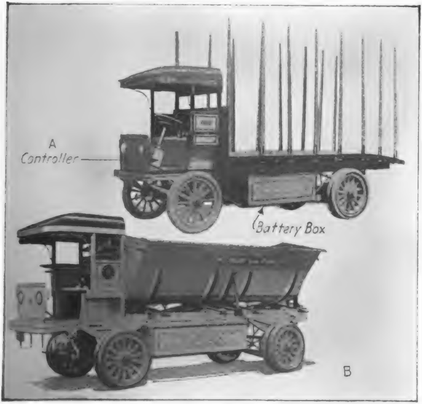


Fig. 472.—Commercial Electric Truck Types.

Rear Construction.—Concentric gear cases of crucible steel, mounted between two axle members, are secured by heavy integral keys and bolts. The rear springs are seated on the top of the gear cases, and the extension of the case, which is made of a die-forged, heat-treated alloy steel, forms the axle spindle. The motor is bolted to the inner side of the gear cases in a fixed position and in line with the axle. The armature pinion, which is made of a high-grade alloy steel and case hardened, engages three case-hardened spur gears, which are carried by studs mounted integral with the driving shaft. The pinions, which are made integral with these intermediate gears, as shown by illustration, engage a single internal gear, which is pressed into and keyed to the gear case, as shown at Fig. 473. The driving shaft passes through the axle spindle and connects with the outer end of the wheel hub through the hub cap, which is made of heavy steel. The driving shaft has no bearing in the axle spindle,

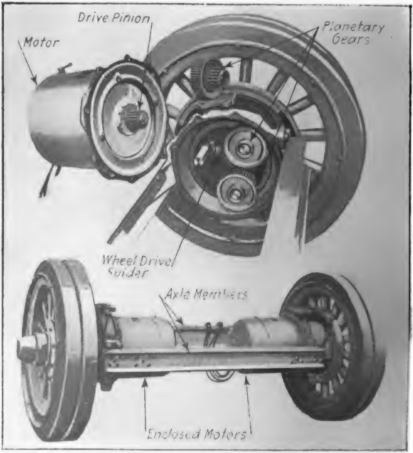

Drive Pinion
Planetary Gears
Motor
Wheel Drive Spider
Axle Members
Enclosed Motors

Fig. 473.—Driving Gearing of Commercial Electric Trucks.

by Google

the driving gears and driving shaft being supported and held in proper position in the following manner: The double intermediate gear has a cylindrical extension formed on its inner end exactly equal to the pitch diameter of the small gear. A cylindrical track is formed in the motor head, the diameter of which is equal to the pitch diameter of the internal gear. It will thus be seen that the three bearings form a perfect rolling support for the inner end of the driving system.

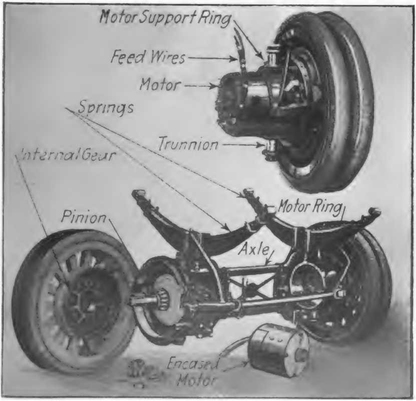


Fig. 474.—Internal Gear Drive Axle of Commercial Electric Truck.

Four Wheel Drive Advantages.—In the development of light and medium capacity power vehicles, the practically universal system of driving with the rear wheels has met with general success. But on heavy trucks, when loads to be carried exceed 5,000 to 6,000 pounds, and which are to be used at times under severe service conditions, the limitations of this system are a serious obstacle to complete success.

This is due to the fact that only a limited amount of the total weight can be carried on the driving wheels, with the result that when streets are covered with ice or blocked with snow, or when heavy grades are encountered, lack of sufficient traction will frequently cause delays and may even make it necessary to call for help. Traction chains or other devices are used to increase the grip on the road, but they are far from satisfactory, as they do not always stand up on heavy high-speed trucks and unless very carefully fitted they increase the wear and tear on the truck, decrease the life of tires and are a source of delay when they break in service.

Thus it has long been recognized that for heavy hauling under severe conditions, the four-wheel drive is desirable and necessary, if the truck is to be depended upon to do its quota of work at all times, regardless of grades, roads, or weather conditions.

Motor Wheel Assembly, Internal Gear Drive.—The motor, which is a standard truck type, series wound, with a cylindrical steel frame, is carried in a high-grade crucible steel casing. The casting is accurately bored to a size that will allow the motor to be slipped in place freely up to a definite shoulder, the case being split part way around and horizontally, so that by tightening up a heavy bolt through lugs cast on this part of the case, the case is securely clamped around the outside of the motor. The motor is thus easily removable without disturbing any other part of the construction, as clearly shown at Fig. 474.

The gearing between the motor and wheel consists of straight spur gears of ample proportions to do the work. The first pinion is made of alloy steel and case hardened, and is mounted directly on the tapered armature shaft with a key. The double intermediate gear is carried by a roller bearing on an intermediate stud, which is case hardened and ground, the stud being supported in the same casting which carries the motor. The teeth and bore of the intermediate pinion are case hardened and ground. The intermediate pinion engages an internal gear mounted directly on the wheel hub. The outside surface of the internal gear forms a brake drum. The axle spindle is so constructed as to form an extension of the gear and motor case, the spindle being approximately in line with the center of the motor.

Battery Compartment.—As shown by illustration at Fig. 472, A and B, the battery is carried in a compartment at approximately the center of the truck. There are a number of advantages of the underslung battery, among which may be mentioned the following: To obtain the best all-round results, including traction and tire life, the weight distribution between the front and rear wheels should be as nearly uniform as possible, whether loaded or empty. This can only be obtained with the battery at approximately the center of the truck.

It is evident that with a low center of gravity there is less tendency when turning corners for the weight to be thrown from the inside to the outside wheels, and, therefore, less tendency to skid. The underslung battery makes the shortest possible truck, which is not only an advantage in traffic as it permits turning in narrow places, and takes up less space in the garage.

Fig. 475.—Fleet of Walker Trucks.

Where there are a number of trucks in a garage this is a decided advantage. In a properly equipped garage the batteries are all flushed at one point and it is not necessary to leave any space between trucks for this purpose.

Proportions of Battery Compartment.—On account of motors and driving gears all being concentrated in the front and rear constructions, ample room is available for a battery compartment that is relatively long and narrow, which is important both from the standpoint of appearance and service, as the compartment built in this way is well inside of the wheels and not subject to collision and damage from other vehicles.

Controller.—The controller is of Commercial Truck Company of America special design, continuous torque drum type, mounted on the chassis, and as shown by illustrations Fig. 472, A and B, forms the base of steering mast. Its position places it in the most desirable location for inspection. The contact segments are secured to metal hubs by countersunk machine screws and can, when necessary, be removed in a few minutes with no other tool than a screw-driver. If desirable, the whole drum can be taken out through the top of the controller case by removing the top cap.

The controller gives four speeds forward and two reverse, making acceleration smooth, with no sudden jerks or strains on gearing and tires. Efficiency and smoothness of acceleration is further assured by the series parallel control of motors, which is dependent in a very small degree on resistance. This is very important, particularly where there is much traffic and frequent starting and stopping, the series parallel position making a very efficient, no-resistance, low-speed running point.

Commercial Truck Specifications.—The specifications of various models of the Commercial Truck Company of America which follow show how the various motors and batteries vary in trucks of different capacity. Many of the details of construction are the same in all models. The one-half ton truck has the following characteristics: Load, 1,000 pounds. Seating capacity, bus, 8 passengers. Speed, 13 miles per hour; bus, 16 miles per hour. Mileage, 40 to 60, depending on battery equipment and conditions. Battery: Edison, 60 cells, type A 5; Ironclad Exide, 42 cells, 9 plates per cell; thin plate type, 42 cells, 13 plates per cell. Tires, 3 x 36-inch front, 3 x 36-inch rear. Motors: Two General Electric Company's 12-ampere, 85 volt for lead battery; 17-ampere, 60-volt for Edison battery.

The one-ton model has the following features: Load, 2,000 pounds. Seating capacity, bus, 12 passengers. Speed, 12 miles per hour; bus, 15 miles per hour. Mileage, 40 to 60, depending on battery equipment and conditions. Battery: Edison, 60 cells, type A 6; Ironclad Exide, 42 cells, 11 plates per cell; thin plate type, 42 cells, 17 plates per cell. Motors: Two General Electric Company's 16-ampere, 85-volt for lead battery; 22-ampere, 60-volt for Edison battery. Tires, 3½ x 36-inch front, 4 x 36-inch rear.

The two-ton model has the following specifications: Load, 4,000 pounds. Seating capacity, bus, 24 passengers. Speed, 10 miles per hour; bus, 14 miles per hour. Mileage, 35 to 55, depending on battery equipment and conditions. Battery: Edison, 60 cells, type A 8; Ironclad Exide, 42 cells, 15 plates per cell; thin plate type, 42 cells, 21 plates per cell. Motors: Two General

Electric Company's 22-ampere, 85-volt for lead battery; 32-ampere, 60-volt for Edison battery. Tires, 4 x 36-inch front; 4 x 36-inch dual rear.

The following specifications apply to all models previously enumerated: Gearing, concentric type; double reduction spur direct to wheels; completely enclosed and running in oil. Axles: Front, rectangular box section; rear, full floating type with double I-beam section. Bearings: Axle bearings, taper roller; motor, annular type ball. Frame: Channel section, trussed and thoroughly braced with gussets at corners and hot riveted, rivets being electrically heated. Springs: Silico-manganese oil-treated steel. Controller: Continuous torque type at base of steering column; four points forward, two reverse. Brakes: Internal expanding.

The heavier models have the following features: Three and one-half tons: Load, 7,000 pounds. Speed, 9 miles per hour. Mileage, 30 to 50, depending on battery equipment and conditions. Battery: Lead, 42 cells; 27 thin-plate type; 17 MV Ironclad-Exide; Edison, 60 cells, type A-10. Motors: Four, 85-volt, 16-ampere General Electric for lead battery; four, 60-volt, 22-ampere General Electric for Edison battery. Tires: Front, 3½ x 36-inch, dual, or 6 x 36-inch, single; rear, 4 x 36-inch, dual. Five-ton: Load, 10,000 pounds. Speed, 7 miles per hour. Mileage, 30 to 50, depending on battery equipment and conditions. Battery: 42 cells; 31 thin plate type; 21 MV Ironclad-Exide; Edison, 60 cells, type A-12. Motors: Four, 85-volt, 16-ampere General Electric for lead battery; four, 60-volt, 22-ampere General Electric for Edison battery. Tires: Front, 4 x 36-inch, duel, or 7 x 36 inch, single; rear, 5 x 36 inch, dual.

These features are found in both the three and one-half and five-ton models: Gearing, double reduction spur gearing, direct to wheels, completely enclosed and running in a heavy lubricant. Bearings: Timken, taper roller. Controller: Continuous torque type at base of steering column; four points forward, two reverse. Brakes: External contracting, faced with a hard, bent wood.

Walker Balanced Drive Truck.—This is similar in general features of construction to other electric trucks, but it has a distinctive method of rear axle construction in which the driving motor is built in and drives the rear wheels by means of intermediate spur gears which transmit the power from the armature

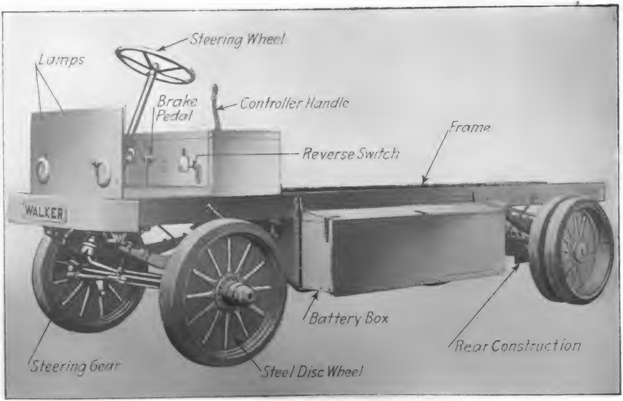

Steering Wheel
Lamps
Brake Pedal
Controller Handle
Frame
Reverse Switch
WALKER
Battery Box
Rear Construction
Steering Gear
Steel Disc Wheel

Fig. 476.—The Walker Balanced Drive Electric Truck Chassis.

shaft pinions to a large internal gear attached to the wheel rim. The Walker chassis is shown at Fig. 476, the view of the rear axle with the top half removed at Fig. 477 shows how the motor field poles are attached to the axle housing castings. The brush carrier is fastened to the top half of the housing, as are two of the field poles. The armature shaft is hollow, which permits passing the long axle shaft through it to the differential gearing at one end of the armature.

The phantom view at Fig. 478 shows clearly the method of driving the wheels and the arrangement of the driving pinions on axle shafts and how the power is transmitted through the two idlers to the internal gear. As considerable difference in diameter exists between the small pinion and the large internal gear, the proper driving reduction is obtained in the gearing. The motor and axle unit is very compact and a good example of electric truck engineering.

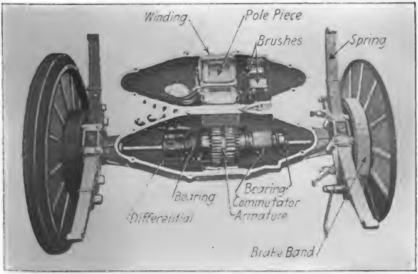


Fig. 477.—Motor and Axle of Walker Balanced Drive Electric Truck.

Batteries for Electric Trucks.—Any practical form of storage battery may be used for automobile propulsion. Either the Edison or lead-plate type batteries prove satisfactory for this work. The lead-plate forms have thin plates to keep the weight down and make for quicker charging and discharging. The usual discharge rate is about two volts per cell, the amperage

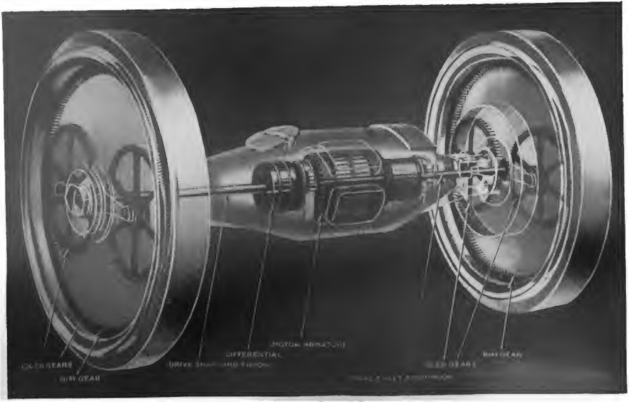

MOTOR ARMATURE
DIFFERENTIAL
IDLER GEARS
RIM GEAR
DRIVE SHAFT AND PINION
IDLER GEARS
RIM GEAR

Fig. 478.—Phantom View of Walker Balanced Drive Axle.

depending upon the resistance to vehicle motion. It is said that the annual maintenance cost of the ordinary lead-plate cell is about 60 per cent. of its original cost. A special vehicle type, called the "Iron Clad," will cost about 30 per cent. of its initial purchase price annually to maintain it in proper condition. The Edison battery occupies about one-third more space than a lead-plate battery of equal capacity, and costs about two and one-half times as much, but it is said to retain its full capacity for three or four years. The lead-plate type will deliver about 10 watt-hours per pound weight; an Edison battery will give nearly 14 watt-hours per pound, according to its makers.

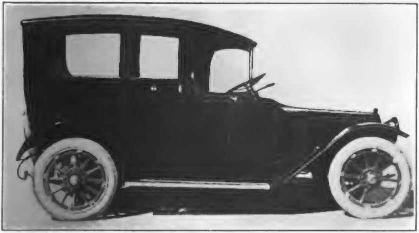


Fig. 479.—Electrically Propelled Taxicab, Having Part of Storage Battery Under Hood and Part Under Rear Seat.

The usual number of lead-plate cells provided to charge from a 110-volt circuit is forty-two or forty-four, having 11, 13 or 15 high-capacity plates per cell, while 60-cell Edison batteries are supplied to meet the same conditions. The battery weight of the average electric vehicle is about 35 per cent. of the total unloaded weight. In order to insure a rate of discharge that will not injure the batteries, electric vehicles are usually geared for moderate speeds, seldom more than 18 to 20 miles per hour for pleasure or passenger-carrying cars on pneumatic tires. Heavy trucks seldom run faster than 6 to 9 miles; medium capacity commercial vehicles may run 10 or 12 miles per hour. A number of electric vehicle makers have adopted a 24-cell battery, using motors wound for about 48 volts.

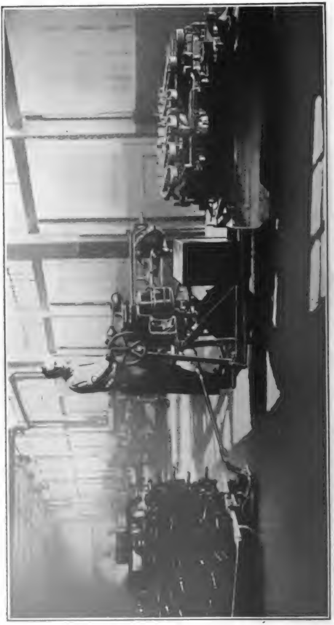


Fig. 480.—Industrial Truck for Factory Work Propelled by Storage Battery.

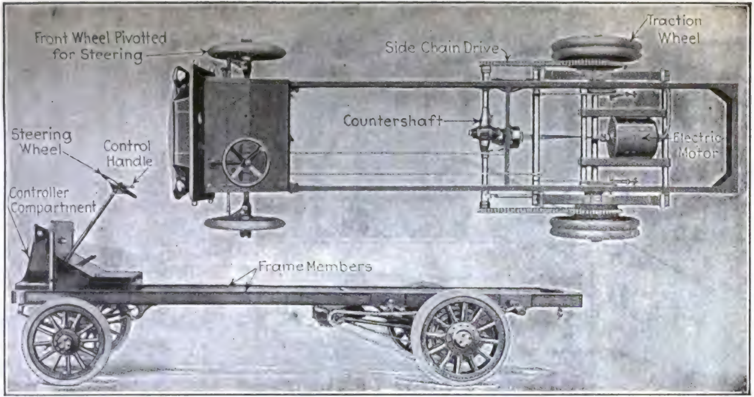

Front Wheel Pivotted for Steering
Side Chain Drive
Traction Wheel
Countershaft
Electric Motor
Steering Wheel
Control Handle
Controller Compartment
Frame Members

Fig. 481.—Plan and Side Views of General Motors Electric Truck Chassis, with Battery Box Removed, Showing Simplicity of Mechanism.

Motors for Electric Automobiles.—The motors used are almost always of the series-wound type, because they provide more power for starting. The usual pleasure-car size is a motor of 2 k.w. rating, or about 2¾ horsepower. Vehicle motors have an overload capacity of 200 to 300 per cent., though, of course, this is practical for only relatively short periods of operation. The speeds are controlled by different combinations of the motor field windings. The power provided on electric trucks is much less than is available in gas-engine propelled trucks, as specifications previously given will make clear.

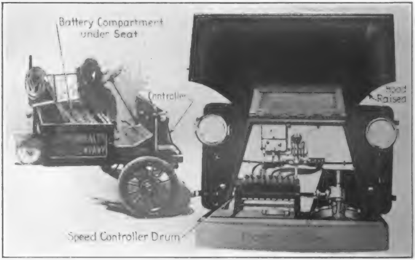


Fig. 482.—View at Left Shows Battery Location; at Right the Controller Compartment is Opened to Show Accessibility of Wiring.

Electric Vehicle Controllers.—In some electric vehicles the various car speeds are obtained by parallel and series parallel combinations of the battery cells. From four to six forward speeds are generally provided, a simple reversing arrangement making it possible to have the same number of reverse speeds if necessary, though this is not always done. Another scheme of control is to have the motor field windings or coils so wired that they may be put in series or in parallel groups. A resistance is used in securing the first speed with the field coils in series. The second speed is obtained by cutting out the resistance and leaving the fields in series. Third speed is obtained by shunting the resistance across the fields, which are still in series. The fourth speed is obtained by leaving the field coils in parallel connection and with resistance out; the fifth speed by shunting the resistance in with the parallel connected fields. The parallel connection gives greater speed, the series field connection more pulling power. A typical controller and its parts is shown at Fig. 483, while an installation at the front of the truck is shown at Fig. 482.

The character of the control to be used on an electric vehicle is dependent upon the class of service to which it is to be supplied. In runabout work a controller is required which will have sufficient number of speeds forward to give an easy acceleration and moderate operating speed with one or more shunt speeds for spurting. In the delivery wagon and truck work, however, high speeds are not required, consequently the controller is built with only sufficient number of forward positions to give easy acceleration and an economical operating position. The question of single and double motor equipment must also be considered.

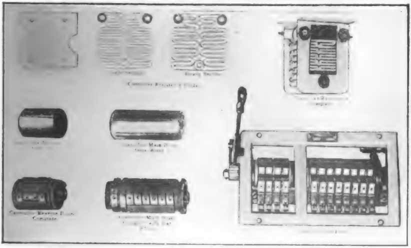


Fig. 483.—Typical Electric Vehicle Speed Controller and Resistance Grids.

The General Electric S 103 type of controller, shown at Fig. 484, A, is designed so that by changing the overall length, the number of contact fingers and cylinder contact arrangement, it can be readily adapted to the various connections required. The

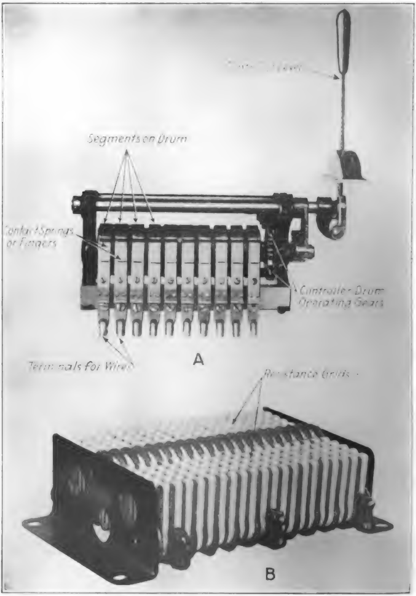

Segments on Drum
Contact Springs or Fingers
Controller Drum Operating Gears
Terminals for Wires
A
Resistance Grids
B

Fig. 484.—General Electric Controller and Resistance Grid Assemblies.

cylinders are of uniform diameter. They are held between end frames of standard design. The cylinder movement is secured by the movement of the gear which is fastened to the cylinder shaft through a section which is moved by the operating handle. By using this form of gear reduction the angle through which the handle moves is greatly reduced in comparison to that through which the cylinder passes.

This not only facilitates the operation of the controller from the seat of the driver but gives a greater displacement between the various notch positions. The controller is designed to be mounted with finger base directed towards the floor of the car, allowing leads to be extended upward and rendering them readily accessible and easy to remove. All contact segments and fingers liable to replacement on account of wear are so designed as to be easily removed. In ordering these parts the controller type and number given on the name-plate should be designated. To secure the best operation of the controller, all moving parts should be regularly filed, and contact segments should be lubricated with vaseline. A finger pressure of 5 pounds has been found to give the best results.

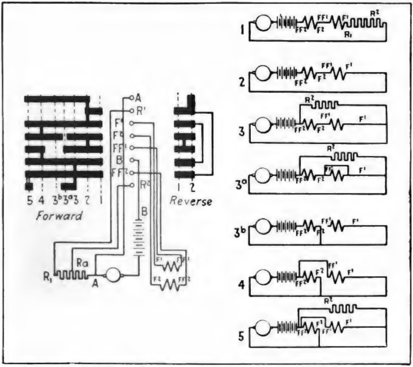


Fig. 485.—Wiring Diagram of G. E. Controller.

Continuous Torque.—All G. E. controllers are designed for continuous torque, the special features of which are given in the

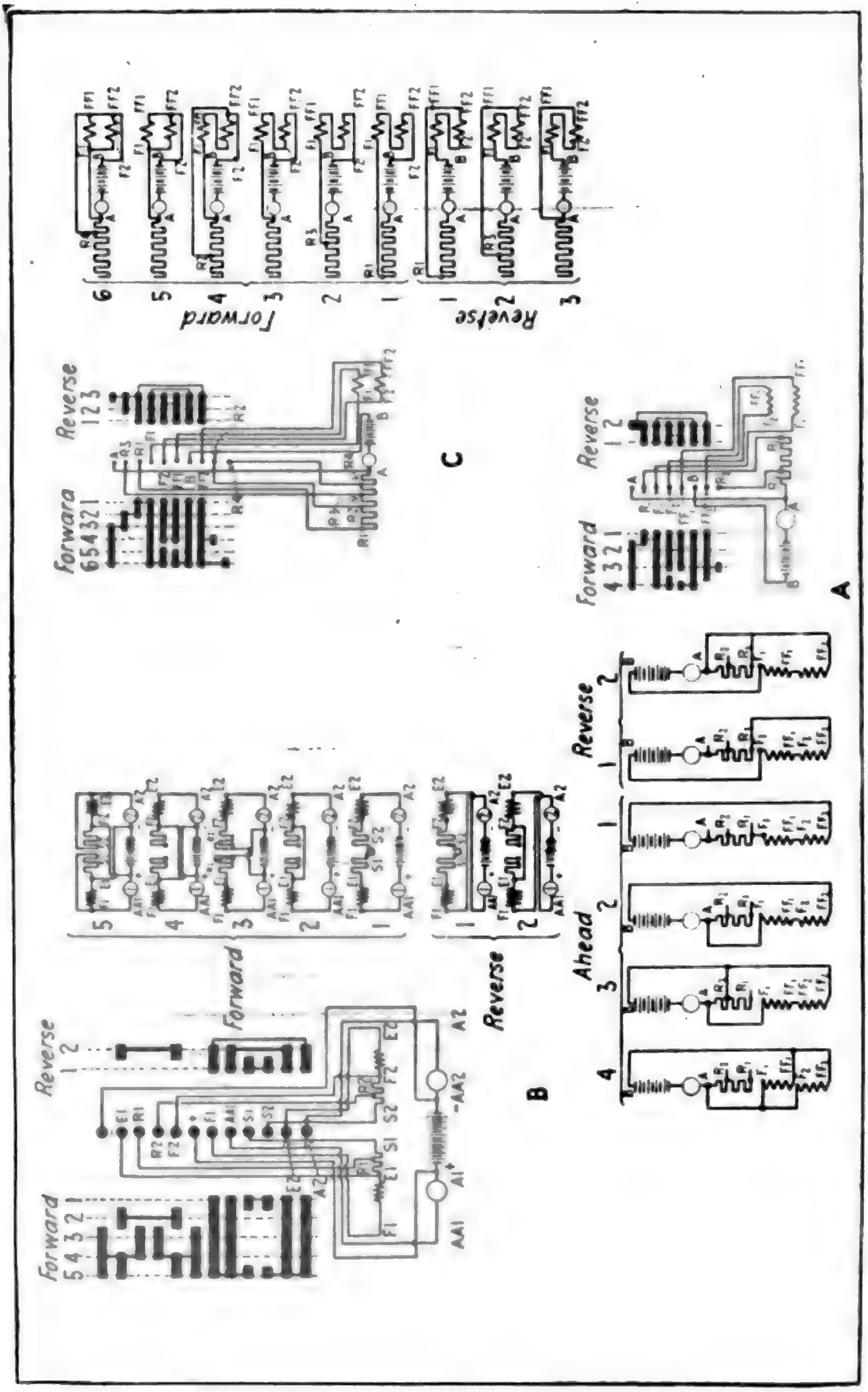

A
B
C
Forward
Reverse
Ahead

Fig. 486.—Wiring Diagrams of Electric Truck Speed Controllers Giving Four, Five and Six Forward Speeds.

following description: To secure smooth acceleration in electric vehicles it is necessary that the current flow uninterruptedly while the controller cylinder is passing to the various forward and reverse notches. In the system of controller used ordinarily in electric vehicles, this interruption will take place only in the transition from the series-to-series parallel point on the controller, the various speeds being secured either by the introduction of series in circuit or by shunting fields.

Referring, therefore, to this one particular point, the continuous torque is applied as indicated on Fig. 485, A, in the following manner: On the third position the motor fields are in series and shunted with resistance R2. As the controller passes between positions three and four, the 3A short circuit is introduced around one set of fields. Referring to the segment layout you will note that this is introduced by the contact finger dropping across the gap on the contacts F2, connecting them to F1 and FF1. In the next position, 3Bm, the shunt R2 is removed. Field connection FF1 is open, leaving field terminal F2 connected to the line F1. Referring again to the contact finger, F2 has now passed across the gap. On the next point, which is the fourth position, the terminal FF1 is connected to FF2.

Reviewing this to accomplish the changes required, the resistance is first introduced across the series field, after which one set of field coils is short-circuited, the other field remaining in full strength. The connection of the resistance and short-circuited fields are now broken, after which the previously short-circuited fields are placed in multiple with the other. Although during the transition only one set of fields are used, it has been found on a four-pole motor, with sets of coils 180° apart, that there is very little momentary increase in operating current. This explanation in question applies to a single motor equipment. For a double motor equipment the general scheme will be the same, except that instead of one motor with series parallel fields we would have two motors in series which would be placed in series parallel.

Wiring diagrams are given at Fig. 486, A, B, and C, showing combinations used on controllers giving four, five and six forward speeds. In view of the explanation previously given no trouble will be experienced in tracing the circuits. In all General Electric continuous torque control, except in one or two special cases, the batteries are kept in series at all times. Referring to the blue-print, they are indicated by one terminal which is marked "B" and another terminal which is connected to the armature.

Resistance.—The G. E. cast grid resistance boxes, one of which is shown at Fig. 484, B, can be made up from three sizes of grids according to the ampere capacity of the service. The boxes are assembled between punched sheet steel and frames in lengths sufficient to give the resistance required. To protect them from rusting, the grids are copper plated and treated with aluminum paint. Care should be taken in handling these boxes prior to their installation in the vehicle and when finally installed they should be firmly held in place.

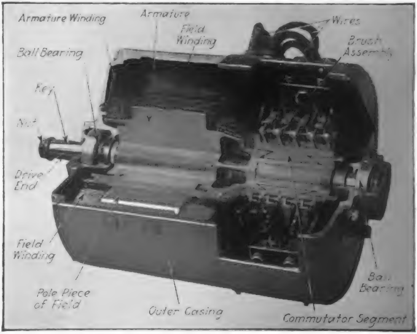

Armature Winding
Armature
Field Winding
Wires
Ball Bearing
Brush Assembly
Key
Nut
Drive End
Field Winding
Ball Bearing
Pole Piece of Field
Outer Casing
Commutator Segment

Fig. 487.—Cut-away View of Westinghouse Electric Vehicle Motor.

Connections.—The notation on the top of the resistance agrees with these on the controller diagram of connections for the particular case to which it is to be applied. There are also connection taps in intermediate positions which can be used to secure speed regulation other than that given by the standard connections.

Westinghouse Vehicle Motors.—The salient characteristics of the Westinghouse motors, one of which is shown in part section at Fig. 487, marking their suitability for application to electric vehicles, are as follows:

1st. The motors are constructed so as to secure strength with a simple arrangement of few parts, which combination attains the much-desired results of minimum attention and maintenance, with long life. Practically the only attention necessary is a periodic inspection for the purpose of renewing brushes when worn and replenishing the lubricant for the bearings.

2nd. The motors are proportioned so as to commutate sparklessly and maintain a high polish on the commutator, even when operating under the severe condition of truck service, where the motors are called upon to commutate from five to six, and even more, times normal rated current.

3rd. A complete line of motors, ranging in capacity from that required for the smallest runabout to that for a ten-ton truck, has been designed and built. Two windings are provided for each size frame—one for the 80-volt and one for the 60-volt classification—to be used principally with lead and Edison batteries respectively. These windings are proportioned so that they deliver equal horsepower at their respective ratings; in other words, the two windings are proportioned so that they have equal watt ratings at the same torque, or turning effort, and the same speed. The full significance of this, and its resulting advantages, may be readily appreciated by considering the fact that a car equipped with one kind of battery may be quickly equipped with the other kind of battery without any change in the motor suspension or mechanical transmission system. Reference to the performance characteristics will make these features clear.

4th. The motors have very high efficiency throughout their range of operation, which characteristic is especially pronounced when operating under conditions of extreme overload.

Construction.—The motor frame shown at Fig. 487 is made of cast steel and is cylindrical in form with one end open and the other end partly enclosed by a flange cast integral. The inside of the frame is cast with a broad boss, or band, which is bored accurately for the pole seat. At each end, the surfaces are machined to receive the bearing housings and hand-hole covers; these parts are attached securely so that the motors are proof against accumulations of dirt and water. The hand-hole covers are attached in a maner so that they may be

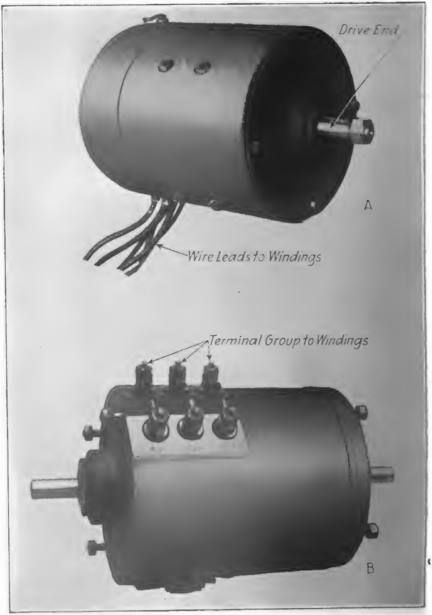

Drive End
A
Wire Leads to Windings
Terminal Group to Windings
B

Fig. 488.—Westinghouse Electric Vehicle Motors.

by Google

removed and the inner parts of the motor inspected readily, and yet the brake rods, etc., may be installed in straight alignment and without offsets.

The poles are built up of very thin laminations made from selected steel sheets, treated by special processes so as to insulate the laminations one from another and enhance the inherently good magnetic qualities. The laminations are assembled in a registering former (the surface of registration being the developed face of the poles) and riveted under pressure. A smooth pole face is thus obtained, as no machine or tool work on the face is permitted after assembly. The pole tips are chamfered to regulate magnetic fringing, but the change in curvature is such that the pole face presents an unbroken surface to the armature core. This construction is such that the eddy current losses are reduced to nearly the vanishing point and quiet operation is assured. While quiet operation is desirable in motors for commercial trucks, it is absolutely necessary in successful pleasure cars.

The bearing houses are constructed so as to prevent the lubricant from working into the motor and are arranged to catch any that may tend to work past the barriers. The lubricant thus gathered is discharged at the outside of the motor through a passage of such proportions and construction that it cannot become clogged with accumulations of dirt and grease. Each bearing housing is fitted with a passage direct from a port at the top to the bearing chamber, so that fresh lubricant may be added without removing the motor from the car. This port is ordinarily fitted with a gas-pipe plug, but may be fitted with compression or other grease cups.

The brush-holders are of the radial sliding box type. They are bolted securely to the frame, but holes are drilled and tapped in the frame so that the brush-holders may be adjusted readily for backward lead for either or both directions of rotation. The brushes are made of high-grade graphite. Braided copper shunts protect the brush springs from the deleterious effects of heating by the current, and are fastened mechanically to the brush without solder, so that there is no danger of this melting and causing the brushes to stick in the brush box.

The armature is built up on a cast iron spider, which permits the removal of the shaft without disturbing the windings. Liberal ventilating ducts are provided, insuring an unrestricted

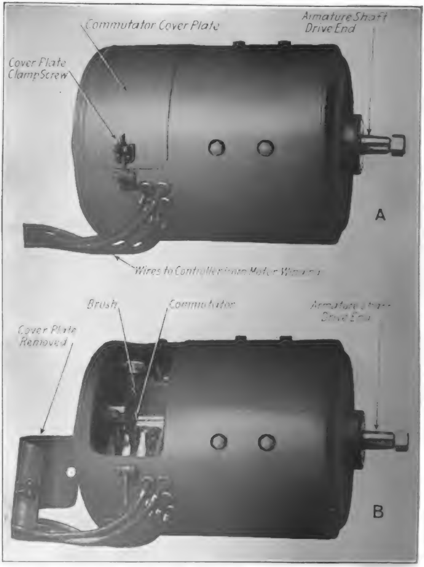

Commutator Cover Plate
Armature Shaft Drive End
Cover Plate Clamp Screw
A
Wires to Controller from Motor Windings
Brush
Commutator
Armature Shaft Drive End
Cover Plate Removed
B

Fig. 489.—Westinghouse Motor for Electric Vehicles is Thoroughly Encased, Yet Commutator and Brushes are Easily Reached.

circulation of air, and the elimination of "localized hot spots," which cause a rapid deterioration of the insulation. The commutator is constructed of a large number of bars, which results in low voltage between bars and consequently excellent commutation. The commutator is clearly shown at Fig. 489, B. The sectional view at Fig. 490 and table of dimensions show the engineering features of these motors.

Westinghouse Vehicle Motor Performance.—During the development stage of the electric vehicle a certain amount of experimental data had to be amassed and analyzed before the

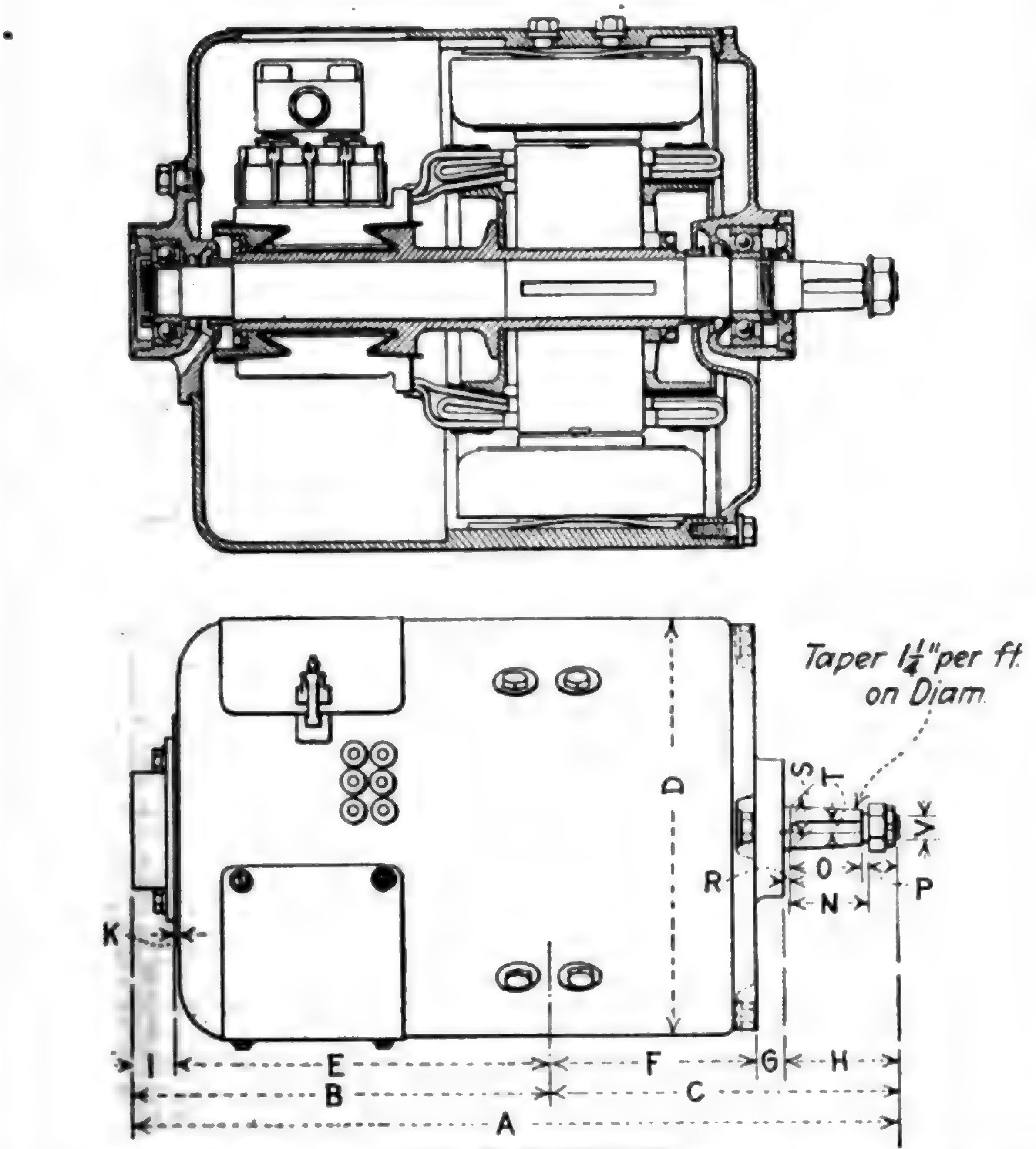


TABLE OF DIMENSIONS

FRAME	A	B	C	D	E	F	G	H	I	K	N	O	P	R	S	T	V
V39	22 11/16	13 3/16	9 1/2	15 3/8	11 5/8	5 3/16	1 1/16	3 3/8	1 11/16	1/8	2	1 7/8	1	1/4	1 7/16	3/8 x 1/8	7/8
V40	20 1/4	11 3/4	8 1/2	13 1/4	10 1/4.	4 11/16	1 1/16	2 3/8	1 1/2	1/8	1 3/4	1 5/8	7/8	1/4	1 1/4 -	5/16 x 1/8	3/4
V43A	29 13/16	16 7/16	13 3/8	16 1/8	14 9/16	8	1 1/8	4 1/2	1 3/4	1/8	3	2 1/8	1 3/8	1/4	1 3/4	3/8 x 1/8	1
V49	24 5/16	14 1/16	10 1/4	15 3/4	12 3/8	6 1/16	1 1/16	3 1/8	1 11/16	1/8	2	1 7/8	1	1/4	1 7/16	3/8 x 1/8	7/8
V50	22 1/4	12 3/4	9 1/2	13 1/8	11 1/4	5 11/16	1 1/16	2 3/4	1 1/2	1/8	1 3/4	1 5/8	7/8	1/4	1 1/4	5/16 x 1/8	3/4
V54B	18 1/16	9 15/16	8 1/8	11 3/8	8 1/16	4 11/32	1 13/32	2 3/4	1 7/8	1/8	1 3/4	1 5/8	7/8	1/4	1 1/4	5/16 x 1/8	3/4
V57B	19 11/32	10	9 11/32	11 7/8	8 1/8	5 5/32	1 1/16	2 3/4	1 7/8	1/8	1 3/4	1 5/8	7/8	1/4	1 1/4	5/16 x 1/8	3/4
V53	31 1/8	17 3/8	13 3/4	17 1/8	15 7/16	8	7/8	4 7/8	1 15/16	1/8	3 1/8	3	1 5/8	1/4	2	1/2 x 5/16	1 1/4

Fig. 490.—Dimensions of Westinghouse Electric Vehicle Motors.

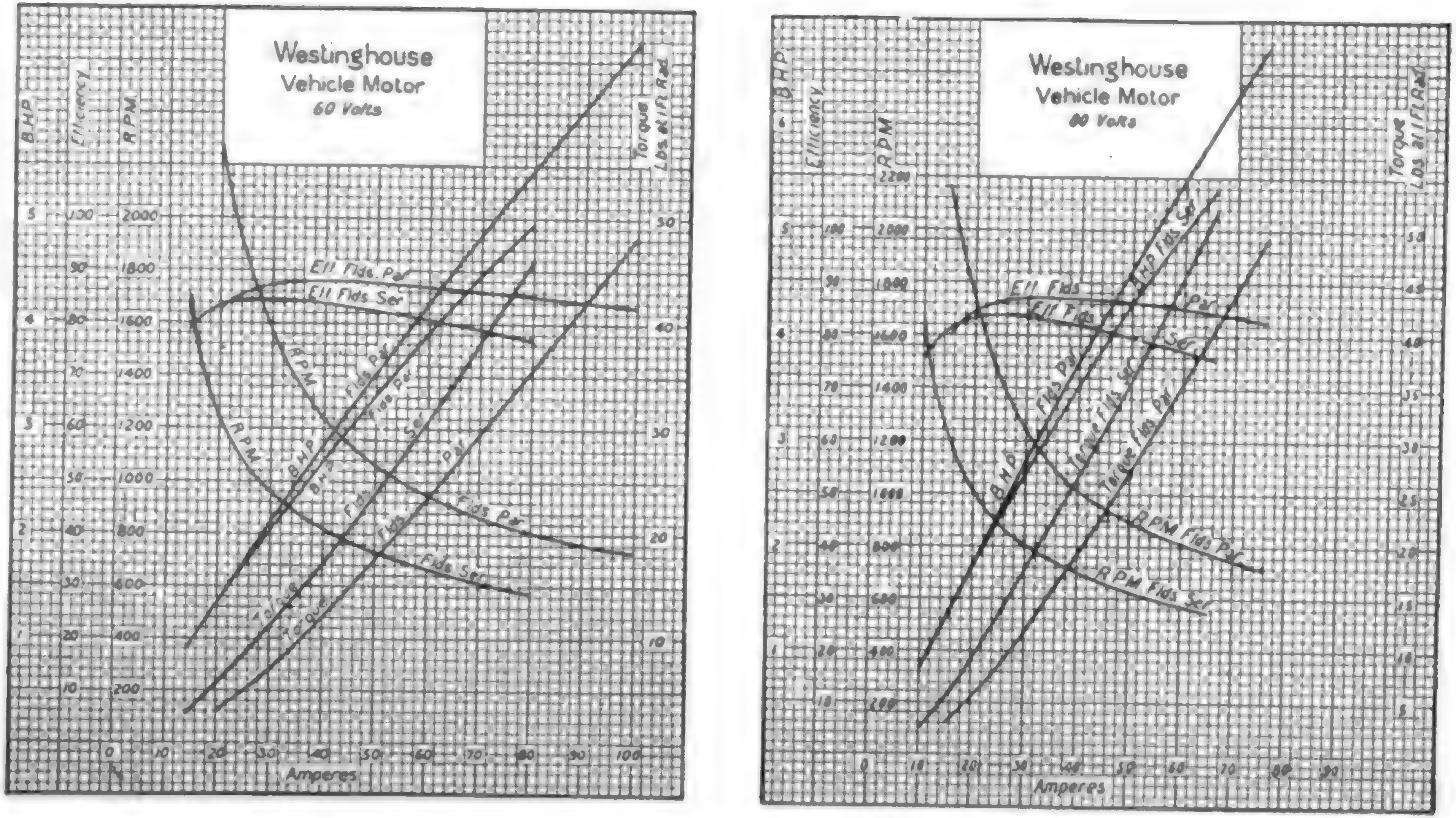


Fig. 491.—Westinghouse Vehicle Motor Performance Curves.

electrical apparatus could be designed and the various pieces selected so as to secure a well-balanced equipment, each piece having a definitely rapid capacity. The importance of establishing a rational relation between the rating of the two principal items, the motor and the storage battery, was clearly seen by the Westinghouse Electric and Manufacturing Company at the beginning of its activities in this field. The very nature of the battery is such that it must be rated as giving out the stored energy at a definite ampere rate for a definite period of time. This was four hours in the early stage of development. Therefore it was decided to arbitrarily rate the motors on the same basis.

The materials used in the construction of the motors are such that a third limitation had to be introduced, namely, increase of temperature above that of the surrounding air. Therefore the motors were rated at a given number of amperes, volts, and r.p.m., with temperature rise of 50° C. above the surrounding air, the temperature to be measured after four hours uninterrupted operation, as shown in charts at Fig. 491. Four hours was selected as conforming with the period of the battery rating, but it was found that many users operated the vehicle until the battery was fully discharged and then replaced it by a freshly charged battery so that the service required from the motor was practically continuous. With motors of the size and construction required for vehicle application the continuous rating is the same, within reasonable limits, as the four-hour rating, so that the temperature rise will be within the safe limit when the motor operates continuously at its normal rating of amperes and volts. It was found that the motors were called upon often during inclement weather to develop a driving effort requiring currents many times the rated value so that a low temperature rise (50° C.) was selected instead of 75° C. rise, as customary for railway motors, which permits the motors to be operated on these extreme overloads for considerable periods of time with a temperature rise sufficiently low so that the motors will not suffer injury.

Description of General Electric Motors.—The General Electric Co. has developed two universal types of motors for battery driven vehicles, one type for trucks to be used in road work and one type for small industrial cars and tractors for use in warehouse and interfactory communication, and for pleasure vehicles operated on roads. The first of these types shown at Figs. 492

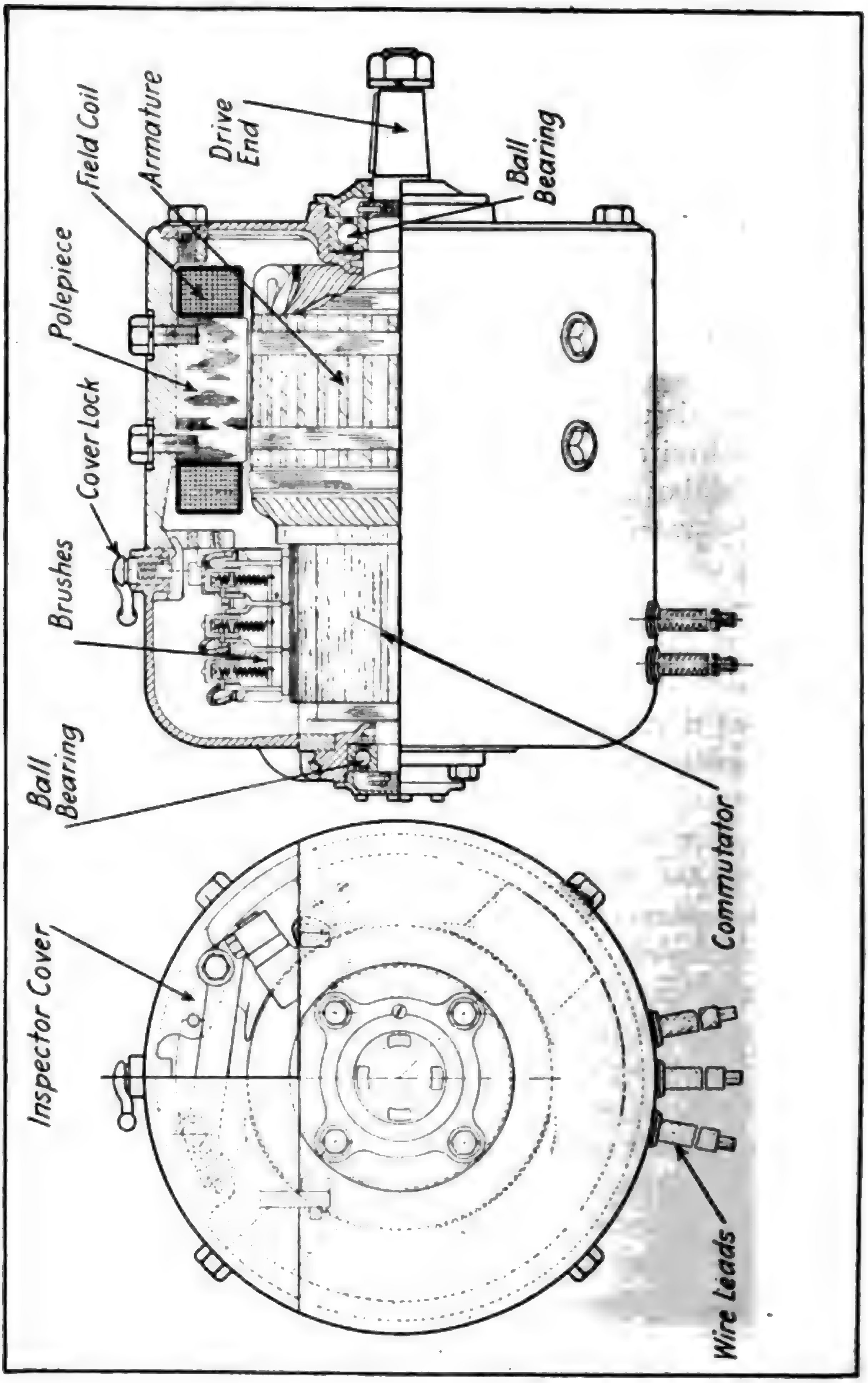

Field Coil
Armature
Drive End
Ball Bearing
Polepiece
Cover Lock
Brushes
Ball Bearing
Commutator
Inspector Cover
Wire Leads

Fig. 492.—General Electric Battery Motor for Electric Vehicles.

and 493 developed in eight (8) sizes of frames, the smallest of which is suitable for the runabout or light delivery wagon, and the largest for the heavy 5-ton truck. The same general mechanical proportions have been followed in all sizes, and the electrical designs have been developed with a view of giving high overload torque and low heating, without undue increase in weight. The following general description covers the mechanical and electrical features of these motors with instructions for their care and operation.

Magnet Frame.—The bearing head commutator end and the magnet frame are a one-piece casting which is machined from end to end. This design readily lends itself to the easy applications of the various forms of suspension brackets which it may be desirable to use. The General Electric Company will drill and tap necessary holes for fastening these brackets if suitable jig is supplied.

Bearing Head and Bearings.—Unless otherwise specified the bearing heads, both commutator and pinion ends, will be made from cast iron, the latter of the closed type. When light weight is required and where the motor is protected from the weather and such moisture as will accumulate in washing, an aluminum end head of the open type can be applied. Annular ball bearings are used on both commutator and pinion ends. They are firmly fastened to the shaft by a retaining nut and are protected from dust by a bearing cap. This cap also acts as a retainer for the lubricant. Before shipment all bearings are packed in refined lubricating grease. This should be renewed every six months, and in case motor is disassembled from vehicle, so that bearings can be taken out, they should be washed with gasoline and repacked with clean vaseline which is free from acid. Shaft extension will be tapered unless otherwise specified, and will extend on the pinion end of the motor. If a brake drum is desired, the shaft can also be extended on the commutator end.

Commutators and Brush Holders.—The mica is milled from the commutators to a depth of $\frac{1}{16}$ inch. Fiber graphite brushes are used. They are held on the commutator with a pressure of 3.5 pounds per square inch on brush contact surface. No lubrication should be used on the commutator and the brush-holder body should be set about $\frac{1}{8}$ inch from the surface of the commutator. Two drilled positions are supplied for setting the brush-holder yoke, and motors can be operated in either clock-

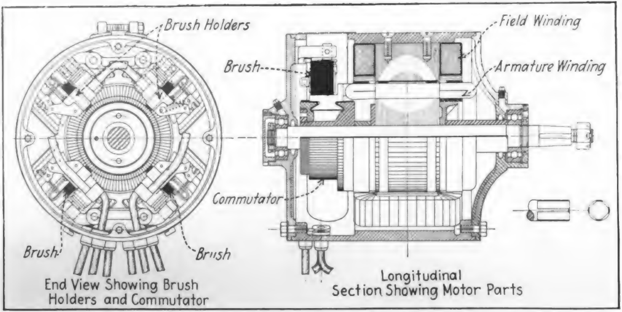

Brush Holders
Brush
Brush
Brush
End View Showing Brush Holders and Commutator
Field Winding
Armature Winding
Brush
Commutator
Longitudinal Section Showing Motor Parts

Fig. 493.—Sectional View Showing Construction of General Electric Vehicle Motors for Industrial and Tractor Work.

wise or counter-clockwise direction of rotation by giving the brushes the necessary backward shift. In case it is necessary at any time to turn the commutator after machining, the milled slots should be carefully cleaned with a sharp file and the surface of the commutator polished with a fine sandpaper. Brushes should be refitted by drawing sandpaper under them in the direction in which the motor operates under normal conditions.

Emery cloth should never be used on commutators or brushes as the hard metallic flakes of the cutting surface become embedded in the softer copper and not only cause excessive wear of the brushes but on account of conductivity develop short-circuit between the segments.

Connections.—The motors are all of the 4-pole design and arranged so that the speed under normal current can be secured with either series or series parallel fields. In the case of the series parallel six (6) leads are brought from the frame, two (2) armatures and four (4) fields; while in the series connections four (4) leads are brought from the frame, two (2) armatures and two (2) fields.

It is possible to rate these motors on 24 or 48 volts if desired, or other voltages which it may be found of a special advantage to use. However, for standard vehicle work using the Edison and lead battery, it has been found that the best charging conditions are secured with the 110-volt circuit where the 80 and 86-volt standard is adopted, the Edison requiring on charge approximately 1.8 volt per cell, and the lead approximately 2 volts per cell.

The second class of motors shown in section at Fig. 493, which have been developed for industrial car and tractor work, are designed to give high overload torque on the lowest possible currents. The machines differ somewhat in construction from those developed for truck work in that they are provided with a 4-brush stud construction, a detail which has permitted the use of the shorter frame, a requirement which is essential in this class of service where space is very limited. The magnet frame is made from a steel casting of the cylindrical construction machined from end to end, while cast iron, steel or malleable iron bearing heads are bolted to each end. The armatures are mounted on ball bearings, the bearing being locked on the shaft with locking nut and the bearing housing closed with a dust-proof bearing cap.

These motors are developed in two sizes of frames, and with standard electrical ratings for 24 and 48 volts. It is possible, however, if occasion requires to supply ratings on other voltages. The armatures on both these types of machine after being wound are baked, dipped in special dipping varnish, baked a second time, the entire operation being repeated twice. The field coils are impregnated in asphaltus under the vacuum process and after being baked are given a final dipping varnish. This renders both armatures and field windings practically impervious to moisture.

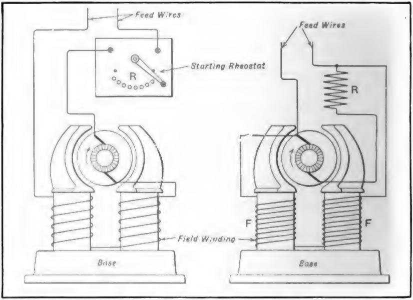


Fig. 494.—Diagram Showing Electric Motor Windings. At left—Series Wound. At Right—Shunt Wound.

Truck Motors and Battery Arrangement.—Electric motors for electric trucks usually have about one kilowatt capacity per ton-load added, the minimum being 2 k.w. on a one-ton truck; thus a two-ton truck will need a 3-k.w. motor, a four-ton truck 4 k.w., and 5 k.w. for a five-ton vehicle. The usual range on good roads is about 40 miles for a truck and 75 to 100 miles for pleasure cars on one battery charge. Vehicle batteries are generally carried in hard-rubber jars and are nearly always of the sealed type on account of the liability of splashing the electrolyte when the car is operated over ordinary highways. The cells are grouped

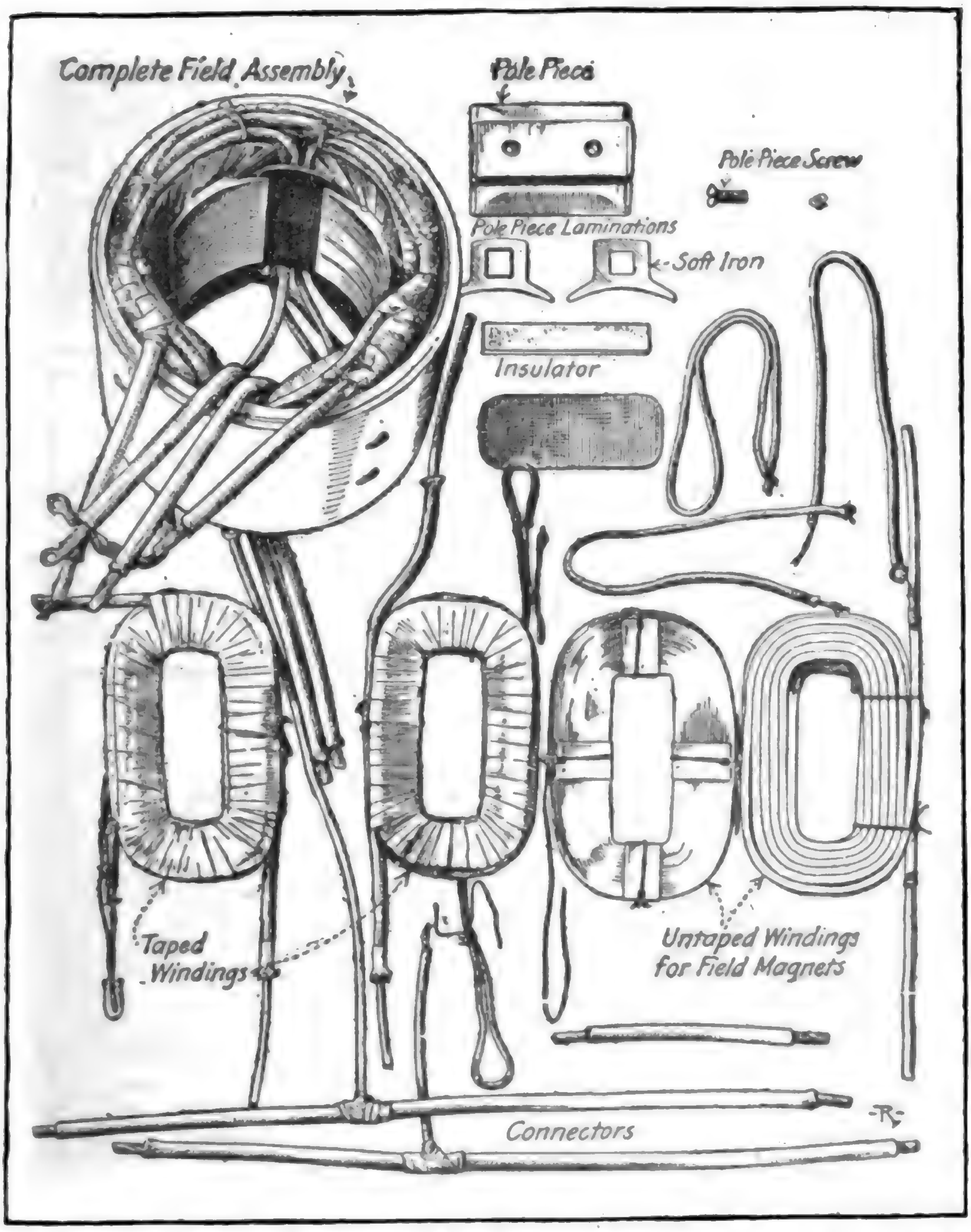

Complete Field Assembly
Pole Piece
Pole Piece Screw
Pole Piece Laminations
Soft Iron
Insulator
Taped Windings
Untaped Windings for Field Magnets
Connectors
R

Fig. 495.—Parts of Typical Four-Pole Motor or Generator Field Assembly.

in trays for easy handling, and all connections and couplings, terminals and battery straps are of unusually rugged design.

The present tendency in lead-battery design seems to be toward the use of more thin plates, as fifteen are furnished as a standard equipment more often than a smaller number. Such an equipment will give 180 ampere-hours, and in some types may develop fully 200 ampere-hours. The reasons for the increasing adoption of the thin plate lead battery are, first, an augmenting demand for more speed and greater range of action per charge, and secondly, a realization on the battery maker's part that the life of a thin plate is equal to that of the heavier ones if the installation is properly made. One standard jar size now being produced will work with from 11 to 15 plates. The high-ribbed type of jar is used, having at least three inches below the bottom of the plates for sediment space, thus reducing the

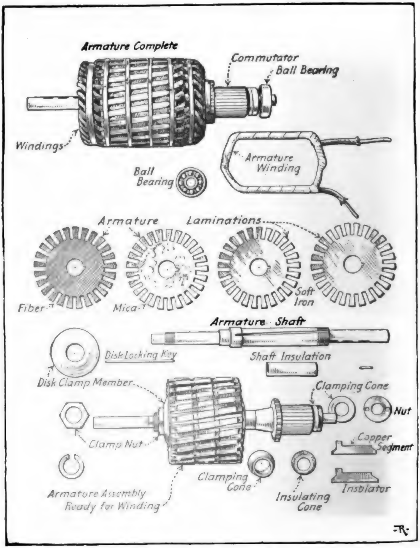

Armature Complete
Commutator
Ball Bearing
Windings
Armature Winding
Ball Bearing
Armature
Laminations
Fiber
Mica
Soft Iron
Armature Shaft
Disk Locking Key
Shaft Insulation
Disk Clamp Member
Clamping Cone
Nut
Clamp Nut
Copper Segment
Clamping Cone
Insulating Cone
Insulator
Armature Assembly Ready for Winding

Fig. 496.—Components of Electric Vehicle Motor Armature Assembly.

amount of washing and necessary cleaning out of the cells. The jars are assembled side to side in trays, with the plate surfaces set at right angles to the direction of car movement. One row of cells is mounted in each tray, these being set lengthwise in the battery compartment. This arrangement is said to reduce jar breakage.

Faults in Motors.—While every effort has been made by the manufacturers of electric trucks to have the various units function as nearly automatically as possible, it will be evident that some attention will be needed by the various units. The motor should be looked over from time to time and should any carbon dust be worn from the brushes by the commutator and deposited in the lower part of the casing it should be blown out with compressed air. It is stated that an accumulation of this dust may result in a ground to the motor case or produce a short-circuit between the brush carrier and case. If the commutator is blackened or rough it must be smoothed down with fine sandpaper while the armature is rotating. Never use emery cloth for this purpose. After smoothing down the commutator remove all

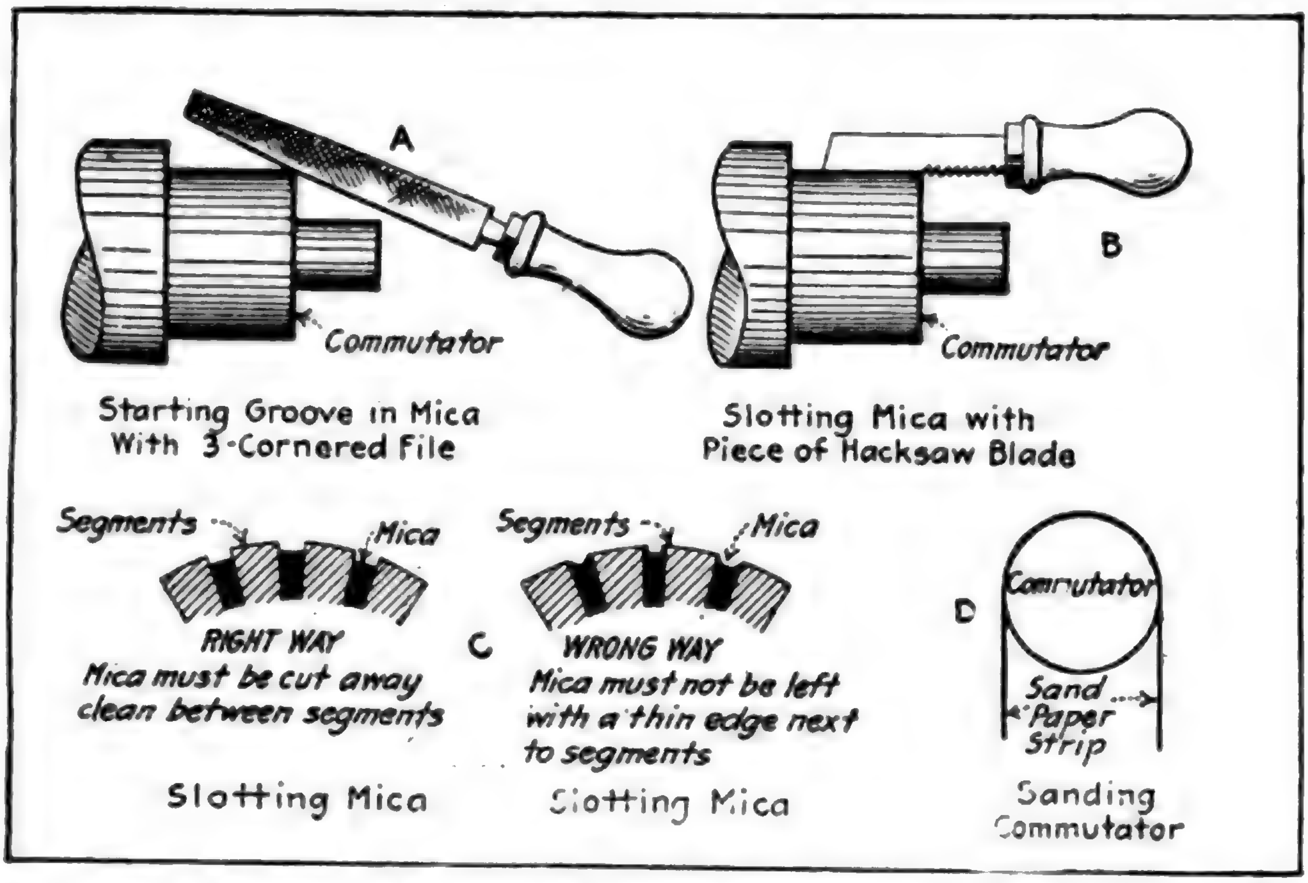

A
Commutator
Starting Groove in Mica
With 3-Cornered File
B
Commutator
Slotting Mica with
Piece of Hacksaw Blade
Segments
Mica
RIGHT WAY
Mica must be cut away clean between segments
Slotting Mica
C
Segments
Mica
WRONG WAY
Mica must not be left with a thin edge next to segments
Slotting Mica
D
Commutator
Sand Paper Strip
Sanding Commutator

Fig. 497.—Methods of Grooving Insulation Between Commutator Segments at A and B and Right and Wrong Way of Slotting the Mica at C. Proper Method of Sanding Small Motor Commutator Outlined at D.

particles of metal which may bridge across between the copper segments. The insulating material between the commutator segments should not be higher than the surfaces of the segment, and if any of it projects it must be filed down slightly lower than the copper pieces by using a small file, as shown at Fig. 497.

The brushes are the part of the motor that demand the most attention and to which most of the troubles in devices of this kind are due. They should be examined to see that they are in perfect contact with the commutator and that they do not stick in the brush-holders. Any dirt or grease on the brush assembly should be removed. One of the most fertile causes of poor brush contact with the commutator is on account of insufficient spring tension. When examining the brushes care should be taken to see that these are maintained positively in contact with the copper segments. Care should be taken not to have the spring pressure too great, as this would produce rapid depreciation of the brushes and heating of the commutator. Brushes that have

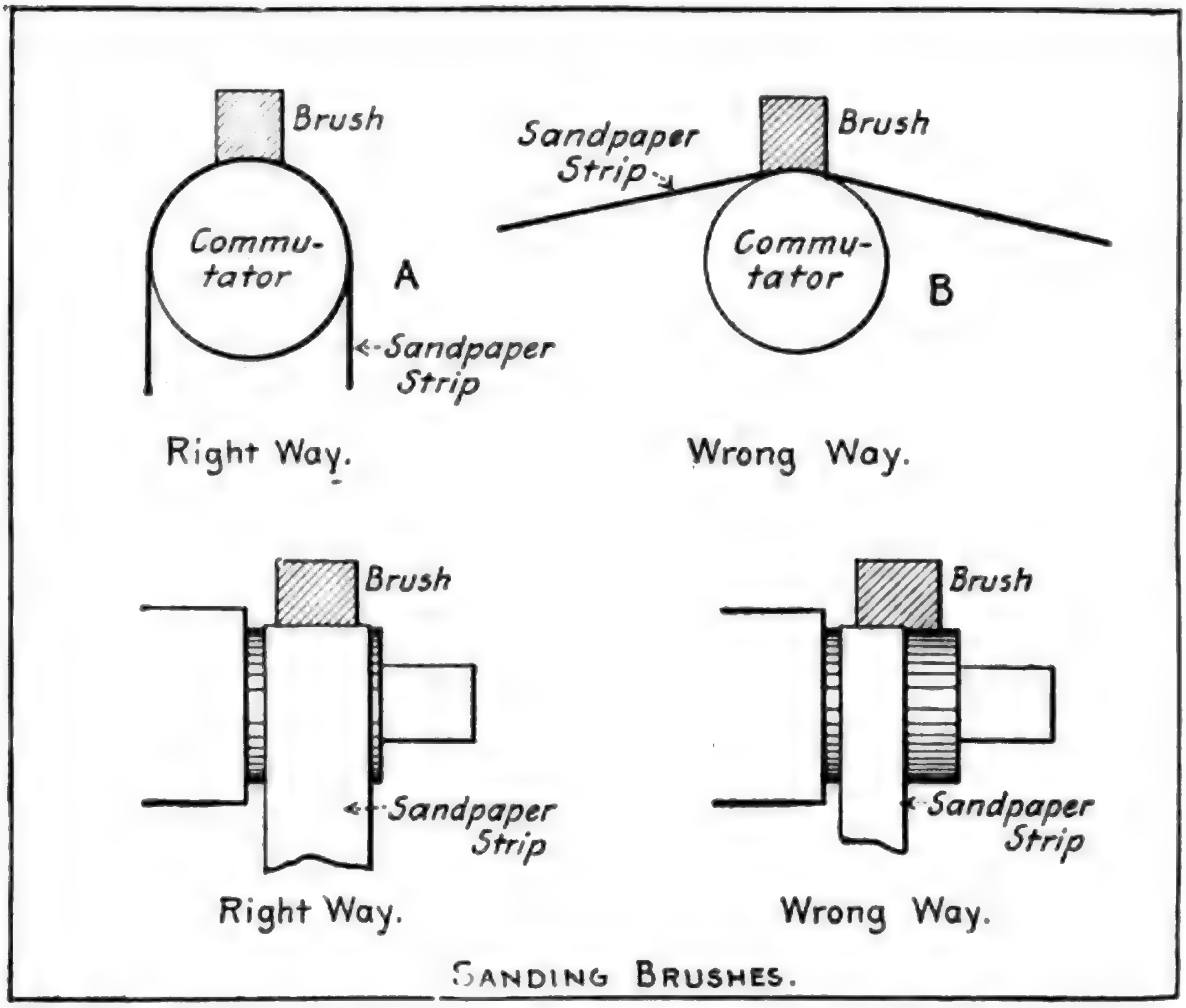

Brush
Commu-tator
A
Sandpaper Strip
Right Way.
Sandpaper Strip
Brush
Commu-tator
B
Wrong Way.
Brush
Sandpaper Strip
Right Way.
Brush
Sandpaper Strip
Wrong Way.
SANDING BRUSHES.

Fig. 498.—Illustration Showing Right and Wrong Way of Sandpapering Brushes.

worn down till they are short must be replaced with new ones. When replacing brushes be sure that they fit the commutator surface exactly over the whole area of the end of the brush, and in all cases use brushes for replacement furnished by the maker of the motor. In some machines shunt connections, which are called "pigtails," are used for connecting the brushes. If the new brushes furnished by the factory have these connections attached care should be taken to make the connection exactly the same as on the old brushes.

It is imperative that the commutator be kept clean, as any oil or grease on the segments will collect carbon dust and produce short-circuiting. The brush-holders should be entirely insulated from the carrying case, and if any of the insulating bushings, washers or plates are found defective they must be replaced with new ones.

Electrical Terms Defined.—In referring to any force, it is necessary to have some units by which its capacity may be judged. For instance, in comparing bodies of different size we can use units which will show the difference of mass or dimensions such as pounds or feet, or the fractions and multiples thereof. To gauge the ability of the electric force there are several practical units with which all motorists should be familiar. They are the volt, watt, ohm and ampere.

The VOLT is the practical unit of electro-motive force, pressure, or difference of potential or condition existing between different parts of the circuit. Referring again to the reservoirs of water, we would find a foot height of liquid a very convenient expression to use as a difference of height or head of water, and such is in constant use by all engineers. This is a precise analogy to the volt, which is the unit that measures the tendency of an electric charge to escape to the opposite level, this being the actuating force of currents. The volt is the cause of the current, not a part of it. It is the difference in voltage which causes a current to flow from one object to another. The expression 100 or any other number of volts current has no foundation; the expression should be 100-volt circuit. The familiar dry cell maintains a difference of about one and one-quarter volts between the surfaces of the elements of which it is composed.

The OHM is the unit by which resistance is judged. Everything has electrical resistance. Some elements have very little, such as a short length of a good conductor; others have so much as to form a most effectual barrier to the passage of the current, these being commonly known as insulators. As an example, consider a man lifting weights. The heavier the weight, the harder he must work to lift it. A little body weighing a few ounces offers so little resistance that it can be raised from the ground with a negligible amount of work. At the other hand, it may have a mass of several hundred pounds, in which case enough resistance would be offered to make it immovable against the efforts of one man, though a number of men might easily move it without mechanical aid.

A substance that would offer considerable resistance to a current of low-tension or voltage would be easily overcome by a current having greater electro-motive force. For instance, it is impossible to pass the current obtained from several cells of dry battery through the air gap between the points of a plug, as the current pressure, only a few volts, is not sufficient to overcome the resistance offered by the air between the electrodes. At the other hand, pass this same battery current through a transformer, such as an induction coil, and it produces another current of greater potential and at high enough voltage to overcome the resistance of the air gap. As an example, a column of mercury one square millimeter in cross section and 1.0624 meters long has the resistance of one ohm.

The unit of current strength or intensity is the AMPERE. Take a conductor of one ohm resistance, maintain a difference of potential of one volt between the ends, and in one second a quantity of current equal to one ampere would have passed through it. A greater voltage will maintain a greater current flow through the same resistance, or a greater resistance will reduce the current in exact proportion. For example, two volts would pass two amperes through one ohm resistance, but would only pass one ampere through two ohms resistance. The ampere is really a unit denoting the rate of flow, and is exactly analogous to a well-known unit used in hydraulics, known as the "miner's inch." This denotes the rate of flow of water which, under a head of six inches, will pass through a hole one inch square in a board two inches thick. Let this head of water represent one volt, and let the resistance of the hole represent one ohm, then the "miner's inch" would represent a current of an ampere.

A WATT is a unit of quantity, or amount of electric energy, and corresponds to a current of one ampere at a pressure of one volt. There are other terms in which a unit of time is compounded with the foregoing, such as ampere-hour, which means that a generator of certain capacity could maintain a current of one ampere for one hour. It is a term usually applied to determine the capacity of a chemical producer. For instance, a storage battery with 60 ampere-hours capacity should supply, theoretically, a current of one ampere for 60 hours, two amperes for 30 hours, or 60 amperes for one hour, or any other combination of time and amperes, which would produce the same result. Electrical rate of work is measured by a unit involving potential difference, quantity of electricity and time. Thus a watt is a volt-ampere-second, and 746 watts indicates an amount of electrical energy equal to one mechanical horsepower.

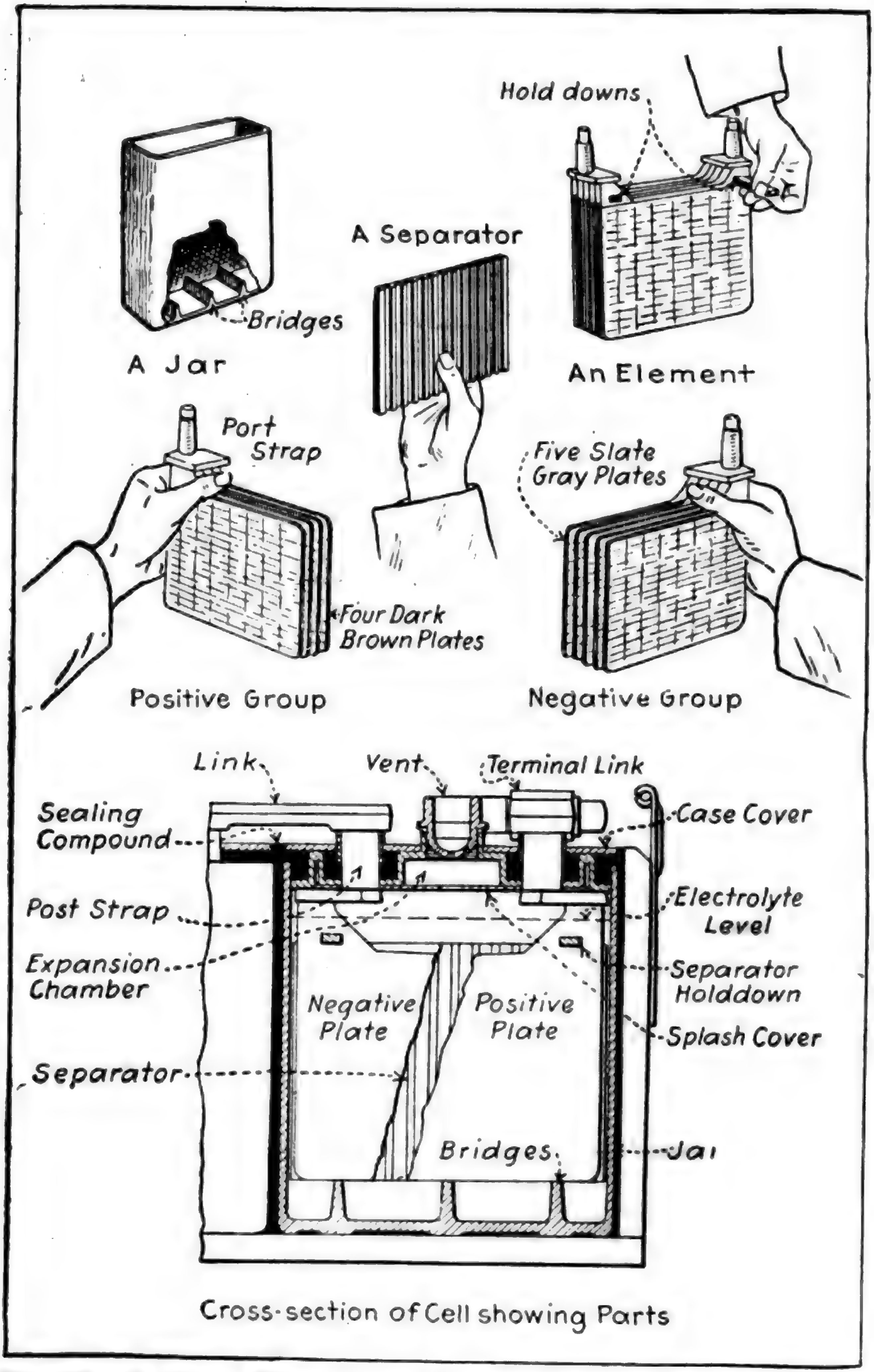

Hold downs
A Separator
Bridges
A Jar
An Element
Port Strap
Five Slate Gray Plates
Four Dark Brown Plates
Positive Group
Negative Group
Link
Vent
Terminal Link
Sealing Compound
Case Cover
Electrolyte Level
Post Strap
Expansion Chamber
Separator Holddown
Negative Plate
Positive Plate
Splash Cover
Separator
Bridges
Jai
Cross-section of Cell showing Parts

Fig. 499.—Sectional View Showing Typical Storage-Battery Cell and Its Principal Parts.

CHAPTER XIV

CONSTRUCTION, CARE AND CHARGING OF TRUCK BATTERIES

Discovery of Reversible Chemical Action—Planté, or Formed Plates—Faure, or Pasted Plates—The Edison Storage Battery—"Iron Clad" Exide Battery—Construction of the Edison Vehicle Battery—Storage Battery Defects—Loss of Battery Capacity—Sediment in Cells—Dangers of Flushing—Sulphation, Cause and Cure—Slow Charge Cures Sulphate—Cause of Plate Deterioration—Making Electrolytes—Equipment for Battery Charging—Charging from Direct Current—Charging from Alternating Current—Mercury Rectifier Bulb—Water Resistance for Discharging—Charging Vehicle Batteries of Lead Plate Type—Maximum Permissible Rate—Ampere Hour Meter Indications as Basis for Charging—Fully Charged Battery—Westinghouse Equipment for Charging Electric Vehicle Batteries.

Discovery of Reversible Chemical Action.—The principle on which storage battery action is based has been known for over a century, as a French scientist, Gautherot, while experimenting with the electrolysis or decomposition of water in 1801 by passing an electric current through it discovered that the silver or platinum wires employed as electrodes for this purpose would send a current of electricity back through a circuit when the battery that furnished the decomposing current was removed from them. The electrical flow from the wires was in a reverse direction to that passed through by the main battery, and was naturally very weak. Further studies by other scientists, notably De la Rue, Ritter and Grove, led to the development of a gas battery which was really a variation of the apparatus used in the electrolysis of water.

In 1834 Faraday made experiments with lead electrodes that resulted in the development of storage battery forms from which those used to-day are patterned. Following the experiments of Sinsteden, who used plates of nickel, silver and lead in a voltampmeter in 1854 and obtained reverse currents from that instrument of sufficient power to raise a wire to red heat after it had been used in measuring a source of electricity, Gaston Planté, who was familiar with these experiments, did the experimental work that formed the basis for the practical storage battery of to-day.

Early Battery Types.—The early Planté battery consisted of two sheets of lead, which were separated from each other by canvas and immersed in a sulphuric acid and water electrolyte. After sending a current of electricity through from primary cells of the Bunsen type, a much more powerful current was obtained from the lead plates that either Faraday, with his lead peroxide element, or Sinsteden, with his combination of metals, had secured, and as a result he is generally credited as being the inventor of the storage battery. After considerable experimenting Planté found that it was possible to increase the current output of a secondary battery by repeated charges and discharges. It was learned that the capacity augmented with use, and that the lead plate surfaces were changed into lead sulphate and lead oxide, and that the coatings penetrated deeper into the plate with each added charge and discharge.

Inasmuch as the knowledge was available to men of science even at that early day (1860) that the action of electric current on lead plates would cause a chemical change that would in turn result in a reverse current flow, the only drawback to making the storage battery of practical value was the lack of economical means for charging the plates. The dynamo had not been perfected to the point that it reached a few years later, so the only current means available for "forming" or preparing the lead plates was by the action of expensive primary batteries. The first chemical changes that took place were of very limited depth, and even after long service the chemical action of changed material could hardly be measured. It was only by frequent and repeated charges and discharges, extending over months of time, that it was possible to obtain cells with sufficient capacity to be of practical value. Even though laboring under these disadvantages, Planté was able to make numerous cells of this kind and perform laboratory experiments which created great interest among the scientists of that time.

The chemical change which results in the production of electricity in lead plate batteries is rather complicated, and its exact nature is not definitely known even to-day. It was advanced by Planté that the charging action, or rather chemical change when current was passed through the cell from an outside source, resulted in the formation of lead peroxide (PbO_2) on the positive plate and metallic lead on the negative. Both of these were said to be converted into lead oxide (PbO) when the current was drawn from the battery. Later investigations showed that the formation of lead sulphate also was of enough consequence to be taken into consideration. This reaction on discharge is probably about as follows:

Charged Condition Becomes Discharged Condition.

$$\underset{-}{Pb} + 2H_2SO_4 + \underset{+}{PbO_2} = \underset{-}{PbSO_4} + 2H_2 + \underset{+}{PbSO_4}.$$

Therefore, during charging, the plates must be brought to their original state and the sulphate driven out of the plates into the electrolyte, as expressed chemically in the following:

When Discharged. After Charging.
Positive Plate, $PbSO_4 + O + H_2O = PbO_2 + H_2SO_4$.
Negative Plate, $PbSO_4 + 2H = Pb + H_2SO_4$.

Considering the equations previously outlined, it will be evident that the active material on both plates of a storage battery is changed into lead sulphate when the battery discharges. There are several reasons for considering this theory. The most important is that chemical analysis of a discharged plate has shown large quantities of lead sulphate to exist. The fact that the density of the electrolyte becomes less during the discharge of the cell shows that sulphuric acid is consumed and that water remains. The specific gravity of the electrolyte is greatest when the cell is fully charged. This demonstrates conclusively that during charging the sulphate has been driven out of the plates and into the electrolyte. When a battery is discharged, the sulphate, having been absorbed by the plates, results in a lower specific gravity of the electrolyte. Then, again, considering the matter from an electro-chemist's point of view, it is known that the combination of oxygen and lead as lead oxide would not liberate sufficient electrical energy to account for the voltage of the current produced by the battery on discharge.

Planté, or Formed Plates.—One of the first difficulties met with and one that militated against the development of the practical or commercial type of battery using Planté plates was the great length of time needed and the expensive means of generating the forming current. Later the plates were treated with nitric acid to facilitate the forming action. Other processes have been developed to hasten the formation. In addition to the chemical treatment, which consists of immersing the lead plates in a pickling bath to produce an oxidization before the current acts upon them, there is a mechanical action which will produce the same result and hasten formation. Laminated plates composed of ribbons of lead will form quicker than the solid lead plates, as will elements made up of lead wires or plates where the surface has been grooved with some forming-tool. An electrolyte process consists of making the plate of a lead alloy and eating the foreign matter away to leave a porous lead plate.

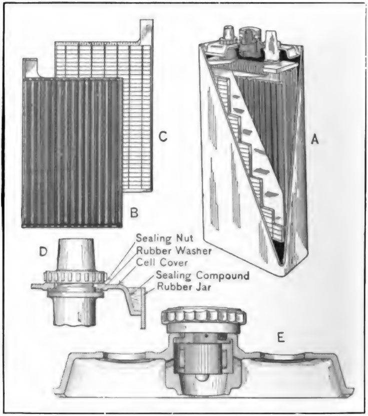


Fig. 500.—Constructional Features of the Exide 'Iron Clad" Vehicle Battery.

Faure, or Pasted Plates.—As soon as it was realized that the result of the forming current was the production of lead peroxide on one of the plates, two men, Camille Faure in France and Charles F. Brush in the United States, working independently of each other, devised a process of plate manufacture that materially reduced the cost of construction. Instead of forming the active material of expensive and time-consuming alternating charges and discharges, the common oxides of lead were applied to the surface of the plate in the form of paste, so that the work required of the electric current was reduced appreciably and considerable weight reduction obtained. Litharge, which is rich in lead, was selected for the negative plates, while red lead, which is oxidized more, was used on the plates intended to be positives. The pastes were composed of the oxides mixed with dilute sulphuric acid in the proportion about one part acid to four of water. Such a paste sets very quickly, and only small quantities can be prepared at a time.

When the Faure process, as it is called, was first discovered, it was believed that the Planté type of plate would be discarded. It was found by practical experience that the new structure developed faults that were not present in the older formation. Pasted plates of early development were found to bend or warp, to enlarge and to shed the active material. In order to eliminate these faults, various ingenious grid patterns were devised.

The capacity of a storage battery depends upon the area and the number of plates per cell, while the potential or voltage is determined by the number of cells joined in the series to form the battery. Each cell has a difference of potential of $2\frac{2}{10}$ volts when fully charged; therefore, a two-cell battery will deliver a current of $4\frac{4}{10}$ volts, and a three-cell type as used for gasoline engine ignition and starting purposes will give about $6\frac{6}{10}$ volts between the terminals. When sets are used in parallel it is advisable to test the sets separately. If one set is doing a large proportion of the work, the gravity of the electrolyte will be different in the sets. It is advisable to change parallel sets to series, when practicable, for charging at terminal stations. This insures the same charge being put in each set. For similar reasons all the cells used in a set should be in the same condition and equally well charged to prevent one or more cells reversing in service.

The Edison Storage Battery.—The fundamental principle of the Edison storage battery, shown at Fig. 502, is the oxidization and reduction of metals in an electrolyte which neither com-

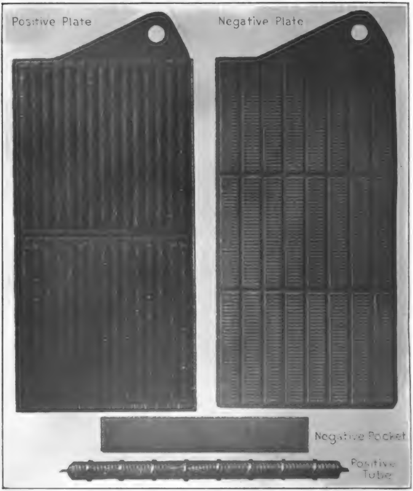


Fig. 501.—Positive and Negative Plates Used in the Edison Alkaline Battery.

bines with nor dissolves either the active materials or their oxides. Also, an electrolyte which, notwithstanding its decomposition by the action of the electric current, is immediately reformed in equal quantity, and is, therefore, a practically constant element without change of density or conductivity over long periods of time. A storage battery is commonly looked upon as a receptacle in which to store electricity. Electricity is not concrete matter. In fact, nobody knows just what it is. Therefore, in the general comprehension of the term, it is not stored. Electricity simply causes a chemical change to be effected in certain substances, when it is caused to flow through them. These substances, in endeavoring to return to their original state, produce electricity.

The following elementary explanation of the action of the non-acid battery is given by the Edison Storage Battery Company, and is so simply expressed and easily understood that it is reproduced in full. If the reader grasps the principles expressed, he will have no difficulty in understanding the chemical action that results in current production.

"Suppose we place two pieces of very thin, bright steel out of doors for a few weeks. They become 'rusted.' The action of the oxygen on the outer layer of the metal has formed it into an oxide commonly known as 'rust.' Now let us place these two pieces of steel in a solution composed of potash and water, and connect them by wires to a small dynamo. The electricity, in flowing from the dynamo through the solution, from one of the plates to the other and back to the dynamo, changes the rust to metallic iron on one of the plates, but causes the other plate to become 'rusted' twice as much as before. Now let us disconnect the plates from the dynamo and connect them, by means of pieces of wire, to an ammeter (an instrument for measuring electricity). Instantly the excess of oxygen in the rust on the one plate commences to pass back to the bright plate and, by so doing, causes electricity to be generated. Why? Nobody really knows. We have now charged and discharged a primitive storage battery.

"Instead of two thin rusted steel plates, let us mount, say, one hundred such plates, equidistantly spaced, on one rod, and one hundred more on another rod. Now interpose the two groups so the plates of the one group will not touch those of the other and immerse them in a solution of potash. When connected to our dynamo the electricity will flow from one group, through the solution, to the other group, converting the oxide of one group to metallic iron, and increasing the amount of oxide on the other group. We shall be able to get much more electricity from the battery thus formed, because of the greater plate surface exposed. We have thus determined that large surface is necessary.

"Let us next place a quantity of fine particles of iron rust in two perforated flat steel pockets, and, after putting these pockets into potash solution, pass electricity from one to the other,

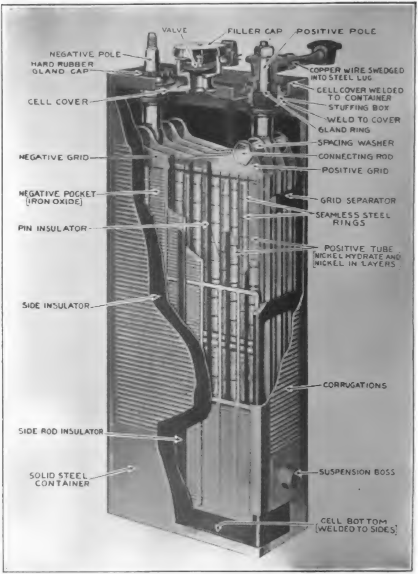

VALVE
FILLER CAP
POSITIVE POLE
NEGATIVE POLE
HARD RUBBER GLAND CAP
COPPER WIRE SWEDGED INTO STEEL LUG
CELL COVER WELDED TO CONTAINER
CELL COVER
STUFFING BOX
WELD TO COVER
GLAND RING
SPACING WASHER
NEGATIVE GRID
CONNECTING ROD
POSITIVE GRID
NEGATIVE POCKET (IRON OXIDE)
GRID SEPARATOR
SEAMLESS STEEL RINGS
PIN INSULATOR
POSITIVE TUBE (NICKEL HYDRATE AND NICKEL IN LAYERS)
SIDE INSULATOR
CORRUGATIONS
SIDE ROD INSULATOR
SOLID STEEL CONTAINER
SUSPENSION BOSS
CELL BOTTOM (WELDED TO SIDES)

Fig. 502.—Part Sectional View of Edison Alkaline Battery, Showing Internal Arrangement of Plates and Relation of Principal Parts to Each Other.

through the solution, as before. All the iron rust in one pocket will be changed to metallic iron, because the oxygen will have passed over to the iron rust in the other pocket, causing this material to possess twice as much oxygen as before.

"Connect the two pockets to your ammeter and you will find that much more electricity is flowing than before, although the two pockets take up much less space than the two hundred steel plates. The reason of this is the small particles present a very great combined surface to the solution. Suppose, after having made a great number of experiments, you put some iron rust or iron oxide into perforated steel pockets, and mount a number of these pockets in a steel grid or support to form one plate and place nickel hydrate (a green powder) in perforated steel receptacles, and mount them on another steel grid to form the other plate, then immerse them in a suitable alkaline electrolyte in any kind of container; you have the essential elements of an Edison cell."

The active material of the positive plate of the Edison storage battery is nickel hydrate; that of the negative plate, iron oxide. The electrolyte is a solution of potassium hydrate. The active materials are perfectly insoluble in the electrolyte. When current passes, either on charge or discharge, the electrolyte is broken up into its component parts, which react on the materials with the following results: On charge—Positive oxidized, negative reduced. On discharge—Positive reduced, negative oxidized. The exact chemical changes that go on within the cell are not definitely known, but those occurring during discharge may be approximately represented by the following equations:

$$\text{Positive: } 8K + 6NiO_2 = 2Ni_3O + 4K_2O.$$
$$\text{Negative: } 8OH + 3Fe = Fe_5O_4 + 4H_2O.$$

The reverse reactions take place on charge. The iron and nickel compounds are probably hydrated, but are here treated as pure oxides, for the sake of simplicity. It will be noted that the same amount of KOH is decomposed, according to the left-hand members of these equations, as is re-formed, simultaneously, as shown on the right. For this reason, the chemical composition, or specific gravity, of the solution does not change appreciably throughout the cycle of charge and discharge.

"Iron Clad" Exide Battery.—The capacity of the conventional pasted type Exide plate rises in service for a time and then gradually becomes less. The initial rating is conservative, however, so that if a battery is given a proper initial charge it will give its rated discharge at the start. This will gradually increase in use, so that the output becomes greater, and then there is a dropping off from the maximum. This rise in capacity when the battery is first put into service results from the increasing porosity of the active material on the positive plate. The more porous this active material the better the electrolyte diffuses through it and more lead peroxide is brought into action on each cycle of charge and discharge. This increase in capacity is evidently made at the expense of the positive active material, because as more is brought into action the active mass becomes softer, and the time comes when some of the material must be dislodged when the battery is charged and it will settle to the cell bottom in the form of sediment. This explains why the life of a battery is shortened by too much charging. The capacity will augment just as long as the rate of increase in the porosity of the active material is greater than the rate at which the active loosens from the plate. After a period of use the loss of material will become greater than the gain in porosity, and it is evident that the cell will begin to lose capacity when this condition is reached.

It is evident that if the positive active material could be prevented from dropping off and still be maintained in a healthy operating condition that the plates would have longer life. While improvements have been made from time to time in the construction of the elements, the new form of positive was evolved. This was accomplished by keeping the active material in position by utilizing a pencil of lead peroxide surrounding a conducting core and enclosed in a porous tube having a sufficient elasticity so that as the active material expanded and contracted. because of alterations in its molecular structure, the containing tube compensated for these variations. The positive plate of the "Iron Clad" Exide consists of an alloy framework comprising top and bottom bars integrally connected by conducting scores of the same metal. The uniform pencils of active material surround these cores and are protected by horizontally laminated rubber tubes.

Each tube is formed with narrow vertical ribs diametrically opposite each other, which take the place of the spacing ribs on the ordinary wooden separator and at the same time re-enforce the tube. By thus protecting the active material and holding it in position it remains active for a considerable time. Excellent conductivity and increased accessibility for the electrolyte are obtained, thereby making it possible to secure a relatively high

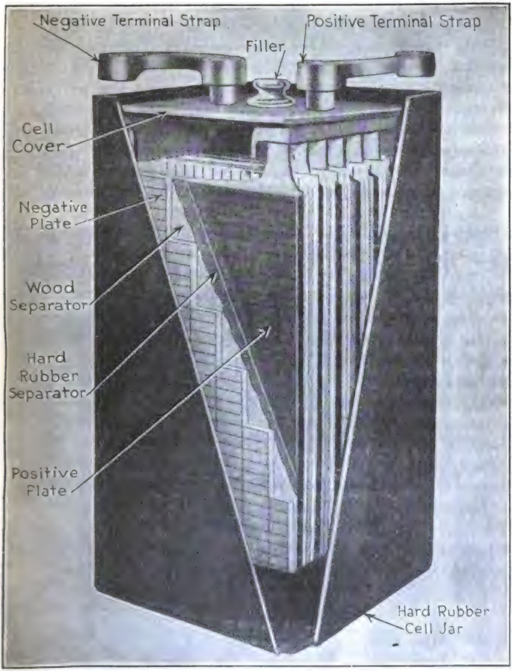

Negative Terminal Strap
Positive Terminal Strap
Filler
Cell Cover
Negative Plate
Wood Separator
Hard Rubber Separator
Positive Plate
Hard Rubber Cell Jar

Fig. 503.—Part Sectional View of Type MV 15 Exide Vehicle Battery.

output from a comparatively small quantity of active material. This battery, which is illustrated at Fig. 500, A, having the positive plate shown at B, was given its name because of its remarkable durability. The negative plate of this battery, which is shown at Fig. 500, C, is of the same general construction as the regular Exide negatives, but is made somewhat thicker in order to compensate for the longer life of the positive plate

The wood separator used between the plates of this battery is a sheet of chemically treated wood and is flat on both sides. No rubber separators are required, inasmuch as the positive plate provides its own separator in having the ribbed rubber tubes to retain the active material. This is a very popular battery for electric vehicle use, because it has a high discharge voltage and is of high efficiency. Flexible pillar strap connectors are regular equipment on "Iron Clad", Exide batteries. Those consist of alloy terminals cast around lead plated copper strips, which give greater conductivity and which are more flexible than the stiff

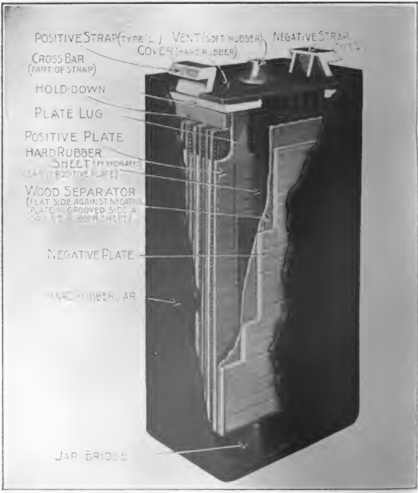

POSITIVE STRAP (TYPE L)
VENT (SOFT RUBBER)
NEGATIVE STRAP
COVER (HARD RUBBER)
CROSS BAR (PART OF STRAP)
HOLD-DOWN
PLATE LUG
POSITIVE PLATE
HARD RUBBER SHEET (PERFORATED AGAINST POSITIVE PLATE)
WOOD SEPARATOR (FLAT SIDE AGAINST NEGATIVE PLATE & GROOVED SIDE AGAINST RUBBER SHEET)
NEGATIVE PLATE
HARD RUBBER JAR
JAR BRIDGE

Fig. 504.—Part Sectional View of **Gould Pasted Plate Cell.**

pillar-strap connectors used with the Exide standard lead plate batteries. The jar is the same as used for the Exide cells of similar size. A special type of vent is provided, which insures positive retention of the electrolyte, yet permits the escape of gas evolved when the battery is charged. The top of the vehicle type cell with vent in place is shown at Fig. 500, E, while the method of sealing is clearly outlined at Fig. 500, D.

Construction of the Edison Vehicle Battery.—This is the only battery built of steel. It is the only storage battery having an alkaline solution and using active materials of nickel hydrate (positive) and iron oxide (negative). This construction and principle are said to have important advantages, and some of these are: It is light in weight. It occupies less space. Requires no spare parts. Its steel container is unbreakable. Requires very little attention. It suffers small loss of charge when idle and does not need frequent hydrometer readings. Its tray assembly and cell connections are simple. It cannot suffer from sulphation or any kindred "disease." Its exclusive use eliminates the need of a battery house. It is not subject to buckling or growing of plates. It may be discharged to zero, or as low as may be desired, without fear of injury. It requires no internal cleaning, the active materials being held securely in perforated steel tubes and pockets. It may be left unused, either charged or discharged, for an indefinite time, without any attention, and suffer no injury. Its cells are hermetically sealed, except for the single filler opening, indicating conclusively that no plate renewals, separator renewals or other repairs are needed or expected. It can be put on charge at any time, regardless of how much or how little of the previous charge has been used; and similarly it may be taken off charge at any time and used, whether fully charged or not.

The positive plates (Fig. 501) consist of a series of perforated steel tubes which are heavily nickel-plated and which are filled with alternate layers of nickel hydroxide and pure metallic nickel in very thin plates. The tube is drawn from a perforated ribbon of steel, nickel-plated, and has a spiral-lapped seam. After being filled with active material it is reinforced with eight steel bands, which prevent the tube expanding away from and breaking contact with its contents. The negative plate consists of a grid of cold-rolled steel, also heavily nickel-plated, holding a number of rectangular pockets filled with powdered iron oxide. These pockets are also made up of finely perforated steel, nickel-plated. After the pockets are filled they are inserted in the grid and subjected to considerable pressure between dies, which corrugate the surfaces of the pockets and force them into positive contact with the grids.

The elements are housed in a jar or container made from cold-rolled steel, which is thoroughly welded at the seams and heavily nickel-plated, as shown at Fig. 502. The plates are assembled in positive and negative groups by means of threaded steel rods passing through holes in one corner of the plates and insulating washers. The terminal post is secured to the middle of the rod. The complete element or plate assembly stands hard rubber bridges on the bottom of the can, and is kept out of contact with the sides of the container by hard rubber spacers attached to the end. The can cover is also of sheet steel, and contains fittings through which the electrodes pass, these being insulated from the cover of bushings of insulating material. A combined filling aperture and vent plug is secured to the center of the cover plate. The general arrangement of the Edison cell parts is clearly outlined at Fig. 502; the plate construction is depicted at Fig. 502, as well as the tubes from the positive plate and pockets used in the negatives.

Storage Battery Defects.—The subject of storage battery maintenance was thoroughly covered in a paper read by H. M. Beck before the S. A. E. and published in the transactions of the society. Some extracts from this are reproduced in connection with notes made by the writer and with excerpts from instruction books of battery manufacturers in order to enable the readers to secure a thorough grasp of this important subject without consulting a mass of literature. Endeavor has been made to simplify the technical points involved and to make the exposition as brief as possible without slighting any essential points. In view of the general adoption of motor starting and lighting systems on all modern automobiles, the repairman or motorist must pay more attention to the electrical apparatus than formerly needed when the simple magneto ignition system was the only electrical part of the automobile. The storage battery is one of the most important parts of the modern electrical systems, and all up-to-date repairmen and electricians must understand its maintenance and charging in order to care for cars of recent manufacture intelligently, as well as being able to understand the many industrial uses considered briefly in this volume.

In taking care of a storage battery, there are four points which are of primary importance:

First: The battery must be charged properly.

Second: The battery must not be overdischarged.

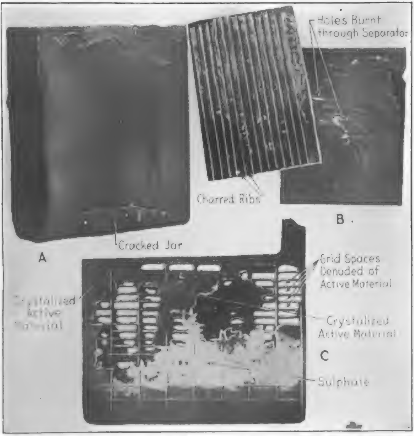

Holes Burnt through Separator
Charred Ribs
B
Cracked Jar
A
Grid Spaces Denuded of Active Material
Crystalized Active Material
Crystalized Active Material
C
Sulphate

Fig. 505.—Defective Parts of Automobile Lighting Battery Abused in Service. A—Cracked Hard Rubber Cell Jar. B—Burnt Wood Separator. C—Badly Damaged Plate.

Third: Short-circuits between the plates, or from sediment under them, must be prevented.

Fourth: The plates must be kept covered with electrolyte, and only water of the proper purity used for replacing evaporation.

According to some authorities the hydrometer test should show the specific gravity of the electrolyte as about 1.208 or 25 degrees Baumé when first prepared for introduction in the cell, and about 1.306 or 34 degrees Baumé when the cell is charged.

The following table gives the corresponding specific gravities and Baumé degrees:

Baumé	Specific Gravity	Baumé	Specific Gravity
0	1.000	18	1.141
1	1.006	19	1.150
2	1.014	20	1.160
3	1.021	21	1.169
4	1.028	22	1.178
5	1.035	23	1.118
6	1.043	24	1.198
7	1.050	25	1.208
8	1.058	26	1.218
9	1.066	27	1.228
10	1.074	28	1.239
11	1.082	29	1.250
12	1.090	30	1.260
13	1.098	31	1.271
14	1.106	32	1.283
15	1.115	33	1.294
16	1.124	34	1.306
17	1.132	35	1.318

The appended conversion formula and table of equivalents will be found of value in changing the reading of a hydrometer, or acidometer, from terms of specific gravity to the Baumé scale or vice versa.

$$\text{Sp. Gr.} = \frac{145}{145 - \text{Baumé degrees}} \text{ at } 60^\circ \text{ F.}$$

Loss of Battery Capacity.—When a battery gives indication of lessened capacity it should be taken apart and the trouble located. If the cells are full of electrolyte, it may be of too low specific gravity. The plates may be sulphated, due to lack of proper charge or too long discharge. The cells may need cleaning, a condition indicated by short capacity and a tendency to overheat when charging. Sometimes a deposit of sediment on the bottom of the cell will short-circuit the plates. If the specific gravity is low and the plates have a whitish appearance, there being little sediment in the cells, it is safe to assume that the plates are sulphated. Sediment should be removed from the cells and the plates rinsed in rain or distilled water to remove particles of dirt or other adhering matter.

Sediment in Cells.—The rate at which the sediment collects depends largely upon the way a battery is handled, and it is therefore necessary to determine this rate for each individual case. A cell should be cut out after, say, fifty charges, the depth of sediment measured and the rate so obtained used to determine the time when the battery will need cleaning. As there is apt to be some variation in the amount of sediment in different cells, and as the sediment is thrown down more rapidly during the latter part of a period than at the beginning, it is always advisable to allow at least one-fourth inch clearance. If the ribs in the bottom of the jars are 1¾ inches high, figure on cleaning when the sediment reaches a depth of 1½ inches. Before dismantling a battery for "washing," if practical, have it fully charged. Otherwise, if the plates are badly sulphated, they are likely to throw down considerable sediment on the charge after the cleaning is completed.

There have been many complaints of lack of capacity from batteries after washing. Almost without exception this is found to be due to lack of a complete charge following the cleaning. The plates are frequently in a sulphated condition when dismantled, and in any case are exposed to the air during the cleaning process, and thus lose more or less of their charge. When reassembled, they consequently need a very complete charge, and in some cases the equivalent of the initial charge, and unless this charge is given the cells will not show capacity and will soon give trouble again. This charge should be as complete as that described elsewhere in connection with the initial charge.

Dangers of Flushing.—"Flushing," or replacing evaporation in cells with electrolyte instead of water, is a most common mistake. The plates of a storage battery must always be kept covered with electrolyte, but the evaporation must be replaced with pure water only. There seems to be a more or less general tendency to confuse the electrolyte of a storage battery with that of a primary cell. The latter becomes weakened as the cell discharges and eventually requires renewal. With the storage battery, however, this is not the case, at least to anything like the same degree, and unless acid is actually lost through slopping or a broken bar it should not be necessary to add anything but water to the cells between cleanings. Acid goes into the plates during discharge, but with proper charging it will all be driven out again, so that there will be practically no loss in the specific gravity readings, or at least one so slight that it does not require adjustment between cleanings.

Thus, unless some of the electrolyte has actually been lost, if the specific gravity readings are low, it is an indication that something is wrong; but the trouble is not that the readings are low, but that something is causing them to be low, and the proper thing to do is to remove the cause and not try to cover it up by doctoring the indicator. The acid is in the cells, and if it does not show in the readings it must be in the form of sulphate, and the proper thing to do is to remove the cause of the sulphation if there is one, and then, with proper charging, drive the acid out of the plates and the specific gravity readings will then come back to the proper point. The too frequent practice in such cases is to add electrolyte to the cells in order to bring up the readings which, as already explained, are only the indication of the trouble, and this further aggravates the condition, until finally the plates become so sulphated that lack of capacity causes a complaint. This practice of adding electrolyte to cells instead of water seems to be becoming more and more common.

Sulphation, Cause and Cure.—When plates are sulphated to restore them to their original condition it is necessary that the battery be given a long, slow charge at about a quarter or a third of the normal charging rate. This should be continued until the electrolyte has reached the proper specific gravity and the voltage has attained its maximum.

It should be understood that sulphating is a normal as well as an abnormal process in the charge and discharge of storage batteries, and the difference is in the degree, not the process. The abnormal condition is that ordinarily referred to by the term. In normal service sulphating does not reach the point where it is difficult to reduce, but if carried too far, the condition becomes so complete that it is difficult to reduce and injury results. A very crude method of illustrating the different degrees of sulphating is to consider it as beginning in individual particles uniformly distributed throughout the active material. Each particle of sulphate is then entirely surrounded by active material. The sulphate itself is a non-conductor, but, being surrounded by active material, the current can reach it from all sides and it is easily reduced. This is normal sulphate. As the action goes further the particles of sulphate become larger and join together and their outside conducting surface is greatly reduced in comparison with their volume, so that it becomes increasingly difficult to reduce them, and we have abnormal sulphate.

Slow Charge Cures Sulphation.—The general cure for sulphating is charging, so that a cell, having been mechanically restored, the electrical restoration consists simply in the proper charging. Sulphate reduces slowly, and on this account it is a good plan to use a rather low current rate. High rates cause excessive gassing, heating, and do not hasten the process appreciably, so that it is the safer as well as the more efficient plan to go slowly. A good rate is about one-fifth normal. The length of charge will depend upon the degree of sulphating. In one actual case it required three months' charging night and day to complete the operation, but this was, of course, an exceptional one. The aim should be no further increase for at least ten hours and an absolute maximum has been reached. In serious cases it may be advisable to even exceed this time in order to make absolutely sure that all sulphate is reduced, and where there is any question it is much safer to charge too long rather than to risk cutting off too soon. A partial charge is only a temporary expedient; the cell, still being sulphated, will drop behind again.

The Gould Storage Battery Company give a number of characteristics by which cells in poor condition may be recognized in addition to the usual hydrometer readings. The plates may be of poor color; the color of a wet positive plate in good condition varies from a rich dark brown (almost black) if the plate is fully charged, to a reddish, fairly dark brown when discharged. A light grayish coating on the positive plates is not a bad indication, if by rubbing with a clean stick or piece of hard rubber a good color is evident immediately under the surface. The color is much lighter for dried plates. The wet negatives are of a light slate gray if charged and somewhat darker if discharged. When dry they are considerably lighter, and may even be somewhat yellowish if allowed to heat in drying. If the color of the plates is not as described they are probably considerably sulphated. If the cell voltage is markedly lower on discharge or higher on charge than it should be, sulphating is also indicated. If the acid strength is low, the cell should be investigated for short-circuits or sulphated plates. Always be sure that the sediment does not touch the plates. It must be removed as soon as there is danger of this occurring.

Cause of Plate Deterioration.—Plates may get in poor condition from the following causes: 1st, Impure Electrolyte: Either a poor quality used at the start, or through the use of impure water or through foreign substances getting into the cells. The remedy in this case, if the plates are physically in fair condition, is to replace the old electrolyte with new, the cells being in a discharged condition, and then thoroughly charge the battery.

2nd, Short-Circuits: These are not frequent if the sediment is removed before it touches the plates, as the wash of the electrolyte in most vehicle batteries resulting from the movement of the car would tend to free them. If they do occur, the cell should be completely dismantled, the plates straightened and the cell assembled again, the separators being completely replaced. The cell should then be thoroughly charged.

3rd, High Temperature: At temperatures above 100° F. corrosion is quite rapid, and this limit must be exceeded. If possible, the temperature should not exceed 90° F. The positive may be sulphated considerably from this cause and the plates grown abnormally and distorted. If they are thoroughly corroded they must be replaced; if not, they should be straightened and thoroughly charged. The conditions should be changed so that the battery will not again be subjected to the high temperature.

4th, Standing Discharged: The positive plates especially may be badly sulphated from this cause. The indication of this condition is a light color of the positive plates, possibly with blotches of a grayish color. The remedy in this case is also complete charge, though care must be taken that too much active material is not thrown off during the charge. Under these conditions the active material is granular and non-cohesive, so care is needed in charging and discharging to restore the plates to efficiency.

Making Electrolyte.—Electrolyte, as used in all lead plate types of batteries, consists of a mixture of pure sulphuric acid and distilled or other pure waters. Concentrated sulphuric acid is a heavy, oily liquid, having a specific gravity of about 1.835. A battery will not operate if the acid is too strong, and it is therefore diluted with sufficient pure water to bring it to a gravity of 1.270 or 1.300 for a fully charged battery. Stronger electrolyte than this is injurious. To prepare electrolyte from sulphuric acid of 1.835 specific gravity, mix with water in the proportions indicated in Fig. 507 for the desired specific gravity, taking the following precautions: Use a glass or earthenware vessel, never metallic. Carefully pour the acid into the water, never water into acid. Stir thoroughly with wooden paddle and allow to cool before reading the gravity.

Both the water and the sulphuric acid used in making electrolyte should be chemically pure to a certain standard. This is

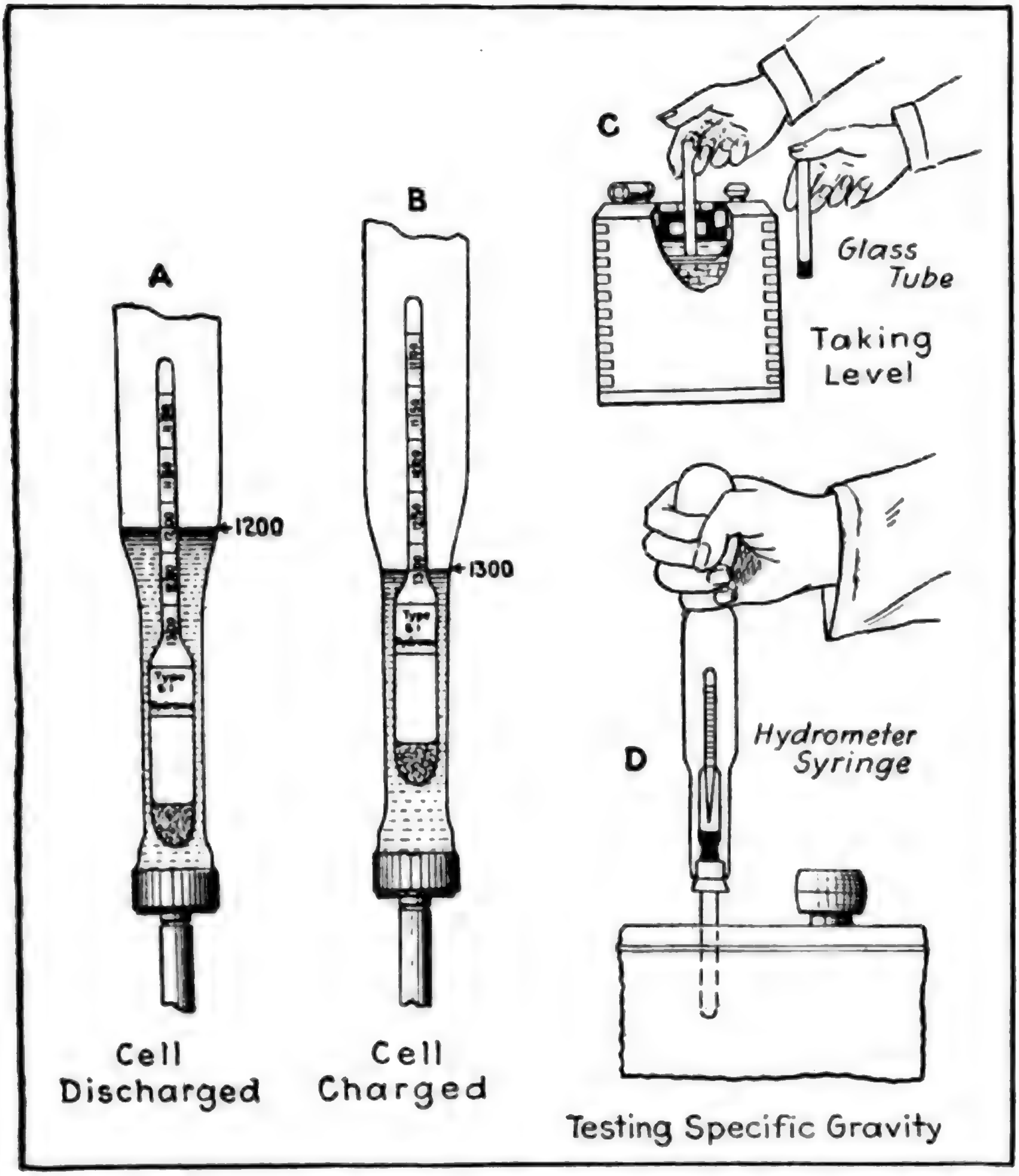

C
Glass Tube
Taking Level
B
A
1200
1300
D
Hydrometer Syringe
Cell Discharged
Cell Charged
Testing Specific Gravity

Fig. 506.—Outlining Positions of Hydrometer in Electrolyte When Cell is Discharged at A and When Cell is Charged at B. Method of Determining Electrolyte Level at C. How to Take Specific Gravity Reading Shown at B.

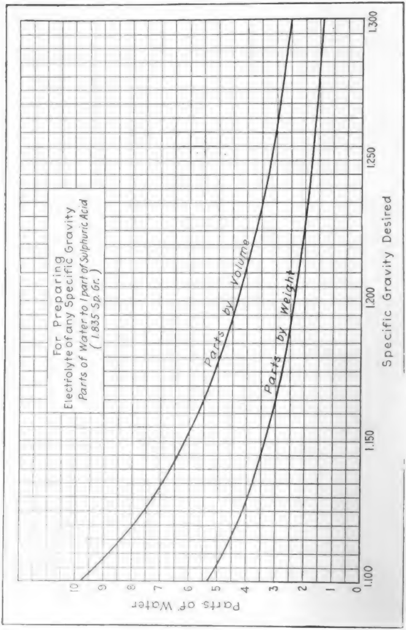


Fig. 507.—Chart for Preparing Electrolyte of Any Specific Gravity.

the same standard of purity as is usually sold in drug stores as "CP" (chemically pure), or by the chemical manufacturers as "battery acid."

Electrolyte made from sulphuric acid meeting the following specifications will be satisfactory:

Sulphuric acid to be high grade, either the so-called "Brimstone Oil of Vitriol" or "Contact Process Acid" made from sulphur of good quality. Must be water-white in color and show no sediment on standing.

By analysis, impurities must not exceed the following:

Platinum	None
Arsenic	Trace
Manganese	Trace
Iron	0.005%
Chloride	0.001%
Nitrogen in any form	0.01 %
Copper	0.002%
Sulphurous acid	None
Organic matter	None

Must be free from all substances other than stated above.

As great care is exercised in the manufacture of storage battery plates and in the furnishing of acid to secure a high degree of purity, obviously attention should be paid to the purity of the water used both in the dilution of concentrated acid, if this is attempted, and replacing the loss cells occasioned by evaporation and overcharge. The frequent addition of water required to replace evaporation leads eventually to a concentration of any impurities which it may contain. As ordinary water supplies are not pure, their use is always questionable. Water from natural sources should be used only with the approval of competent chemists. Rain water should not be used if distilled water is available, as it often contains traces of nitric acid and ammonia, either of which is harmful to storage batteries. Distilled water is preferable and should always be used unless otherwise advised by the chemists. The water should be stored in carboys or thoroughly cleaned whiskey barrels. Water obtained by condensing the exhaust from engines and which may thus contain cylinder oil and other impurities should never be used for battery purposes. In cleaning batteries the ordinary tap water may be used provided it does not contain a great quantity of impurities.

In this connection, the expression "chemically pure" acid is often confused with acid of "full strength." Acid may be of full strength (approximately 1.835 sp. gr.) and at the same time chemically pure. If this chemically pure acid of full strength be mixed with chemically pure water, the mixture would still be chemically pure, but not of full strength. On the other hand, if a small quantity of some impurity be introduced into chemically pure acid, it would not materially reduce the strength, but would make it impure.

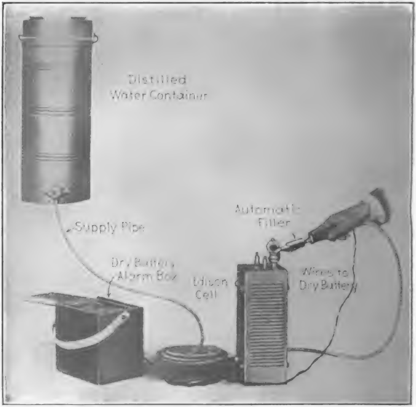

Distilled
Water Container
Supply Pipe
Automatic
Filler
Dry Battery
Alarm Box
Edison
Cell
Wires to
Dry Battery

Fig. 508.—Automatic Filler for Renewing Water Supply in Edison Alkaline Cell.

The usual method of determining the strength of electrolyte is by taking its specific gravity. The method is possible on account of the fact that sulphuric acid is heavier than water. Therefore, the greater the proportion of acid contained in the electrolyte the heavier the solution or the higher its specific gravity. By specific gravity is meant the relative weight of any substance compared with water as a basis. Pure water, therefore, is considered to have a specific gravity of 1, usually written 1.000 and spoken of as "ten hundred." One pound of water is approximately one pint. An equal volume of concentrated sulphuric acid (oil of vitriol) weighs 1.835 pounds. It therefore has a specific gravity of 1.835 and is spoken of as "eighteen thirty-five."

Since electrolyte, like most substances, expands when heated, its specific gravity is affected by a change in temperature. For the convenience of the operator, the following table is given to show the variation in the electrolyte specific gravity at various temperatures likely to be met with in service:

Degrees Fahr.	Specific Gravity
106	1.208
97	1.211
88	1.214
79	1.217
70 normal	1.220 normal
61	1.223
52	1.226
43	1.229
34	1.232
25	1.235
16	1.238
7	1.241

The solution must be allowed to stand several hours to cool. Never add hot or even warm electrolyte to a cell, as the plates are liable to be dangerously sulphated thereby. The strength of the resultant solution should always be checked by hydrometer readings reducing the latter to 70 degrees Fahr.

Features of the Edison Cell.—The instructions given apply only to batteries of the lead plate type and not to the Edison battery, which is entirely different in construction. The Edison cell uses an electrolyte consisting of 21 per cent solution of potash in distilled water, so that the electrolyte is alkaline instead of acidulous. For six-volt ignition and lighting service it is necessary to use five cells owing to the lesser voltage of the Edison batteries. The average voltage during discharge is but 1.2 volts per cell, and is not as constant as is the case with a lead battery, the voltage of which may be as high as 2.5 volts per cell.

An Edison 6.5-volt battery used for lighting or ignition may be charged completely in ten hours. A feature of the Edison battery is that overcharging at the normal rate has no harmful effects, and it is advised by the maker to give the battery a twelve-hour charge once every 60 days or when the electrolyte is replenished. The electrolyte must be kept sufficiently high so as to cover the plates, and any loss by evaporation must be compensated for by the addition of distilled water. Another feature in which the Edison battery is superior to the lead plate type is that the plates will not be injured if the cells are allowed to stand in a discharged condition. The external portions of the cells must be kept clean and dry, because the container or can

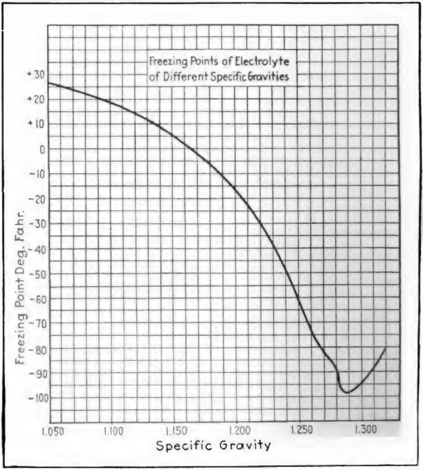


Fig. 509.—Freezing-Points of Battery Electrolyte.

is made of a conducting material. The vent caps must be kept closed, except when replacing electrolyte or bringing the level up to the proper height by adding distilled water. Care should be taken to avoid short-circuiting of the battery by tools or metal objects, and special emphasis is laid on the precaution that no acid or electrolyte containing acid be poured into the cells. It is said that the Edison battery has a longer life than the lead plate type of equal capacity. An automatic filler for Edison cells is shown at Fig. 508.

Equipment for Battery Charging.—The equipment to be used in charging storage batteries depends entirely upon the type and size of batteries to be charged, the current voltage and character available for charging, and the individual characteristics of the batteries themselves. Storage batteries can be charged only with direct current, i.e., that which flows always from the same direction. It is evident that the use of alternating current, if the mains were attached directly to the battery, would result in rapid changes in the interior of the cells, and as the flow in one direction would tend to neutralize that in the other, the plates would depreciate very rapidly. If alternating current is the only kind available, this must be transformed or rectified into direct current. All cells cannot be charged at the same rate. The greater the capacity of the battery and the higher its discharge rate, the greater the amperage of the current that can be used in charging. While the voltage of a storage battery made of certain materials will not vary with the size, the amperage or current output increases with the plate size and number. A lead-plate storage battery no longer than a thimble will have just as high voltage as one as big as a barrel. It will be evident, however, that if too much current is passed through a small cell it will be injured, whereas too little current passed through a large cell will have but little effect on changing the character of the plates.

There are two general methods in use for charging either the sulphuric-acid-lead batteries or the alkali-nickel-iron batteries used in the various commercial applications. The first method, and the one most widely followed, is called the constant-current system. The other system, which has only received attention lately, is called the constant-potential method. Two other schemes are used also which are modifications of the two previously named general methods, one known as the multiple voltage system, the other as a fixed resistance method. The constant potential method is said to offer a number of advantages. There is less evaporation of electrolyte and less shifting of

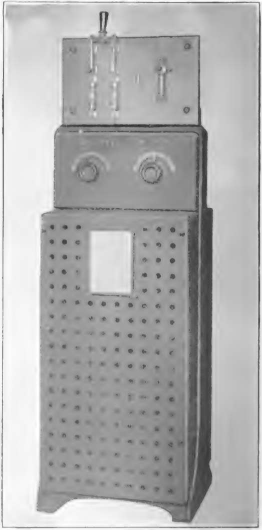


Fig. 510.—Battery Charging Rheostat.

rheostats is needed. Any form of battery may be charged by means of a fixed resistance connected in series. When the battery counter electromotive force is nearly equal to the voltage of the line, this method approximates the general characteristics of the constant potential system. If the voltage of the battery is considerably less than that of the charging current, the characteristics will approximate the constant-current charging method. It may be stated that the variation in the current used for charging is inversely proportional to the difference between the maximum counter voltage of the battery and the potential or voltage of the supply circuit.

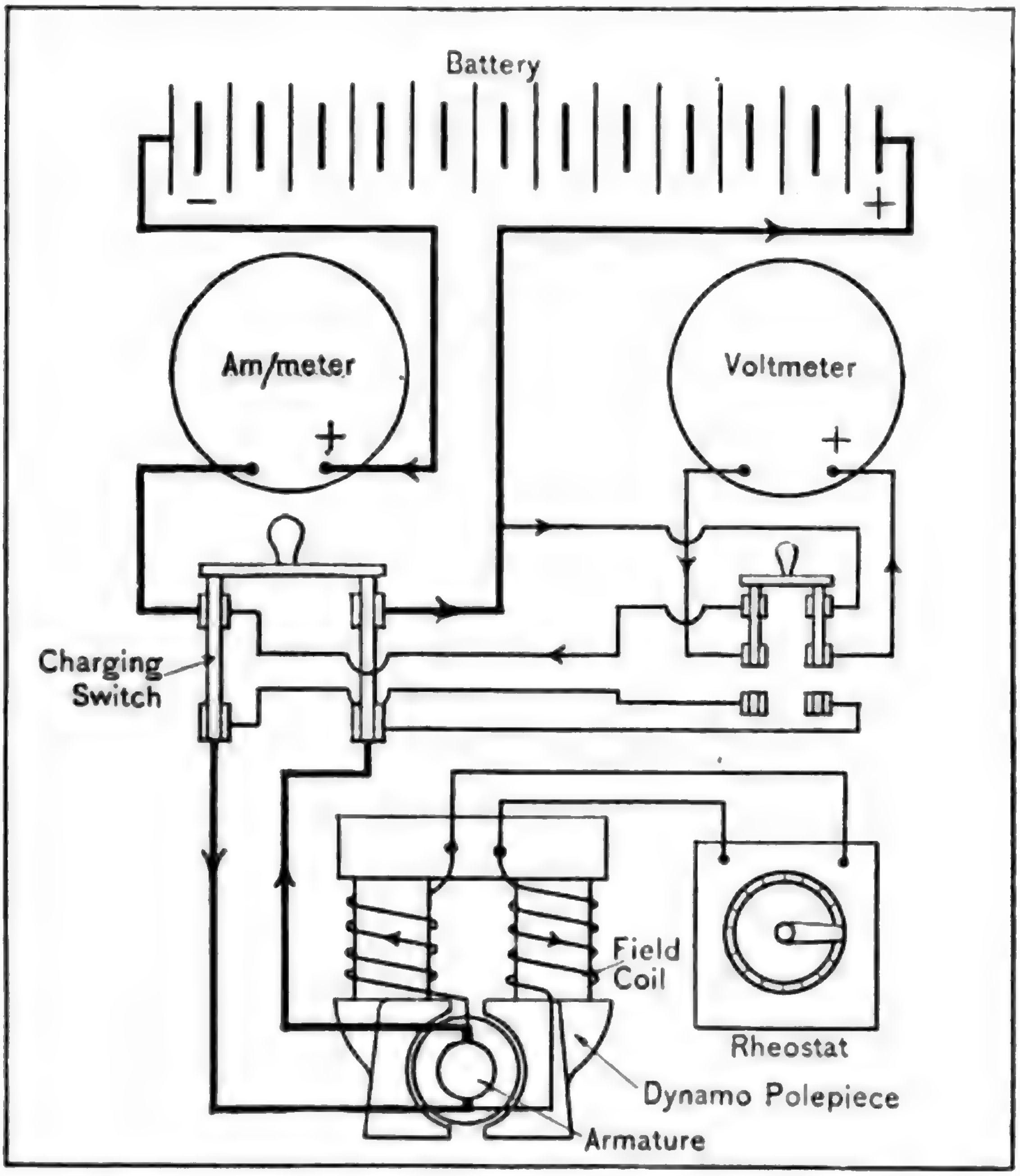


Fig. 511.—Battery-Charging Outfit, Having Field-Coil Rheostat.

Charging from Direct Current.—When a direct current of 110 volts potential is available Edison batteries composed of 60 cells or lead-plate batteries of 40 to 44 cells may be charged directly from the line by means of a rheostat to regulate the amount of current passing through the batteries, which is placed in series with each battery. If the service is of higher voltage, a motor generator or rotary converter set may be used. If alternating current only is available, various types of rectifiers are needed. If only one battery is to be charged and if the voltage of the generator can be adjusted by means of a rheostat connected in series with the field coils of the dynamo, as shown at Fig. 511, then no rheostat will be needed between the battery and the dynamo, because the charging current can be kept to the proper value by varying the dynamo voltage. When a mercury arc rectifier is employed in battery charging, the charging current can be regulated by control dials and a rheostat is not needed. The various types of rectifiers suitable for use with alternating current are to be described in proper sequence. Rotary converters may be used with either direct or alternating current, depending entirely upon the type of motor used. It is evident that the dynamo of such a combination must always be of the direct-current type, though its output will vary according to the power of the actuating motor, the method of winding, and wire used in field armature coils. The motor may be a direct-current type, wound for high voltage, or it may be a type wound to operate on alternating current. (See Fig. 512A.)

Typical Battery Charging System.—The arrangement of the essential parts of a typical battery-charging system where the current value is altered by a dynamo field-coil rheostat is shown at Fig. 511. A shunt-wound generator is employed, and the main leads from the armature brushes are connected to the lower poles of a double-pole knife-switch. The battery is connected to the upper portion of the switch, an amperemeter being placed in circuit as indicated. The hinges of a small double-throw, double-pole switch are connected with a voltmeter. The amperemeter and voltmeter should be of the permanent type. Before throwing in the charging switch it is possible to read the voltage of the battery, and also by throwing the switch to read that of the charging generator so that it may be adjusted to a slightly greater voltage. The main switch is then closed and the rheostat used to raise the voltage sufficiently to drive a suitable charging current through the battery. With a system of this kind a circuit breaker or automatic overload switch should be included in the main line to protect the apparatus in case of accidental short circuit. An underload circuit breaker should also be provided to shut off the battery if the current falls to such a point that the battery will discharge through the generator. These are not shown in the simplified wiring diagram, neither are the fuses that prudence dictates should be used.

Charging from Alternating Current.—In most communities the incandescent lighting circuit is used for charging batteries on account of the voltage of the power circuits being too high. The incandescent lighting circuit may be any one of six forms.

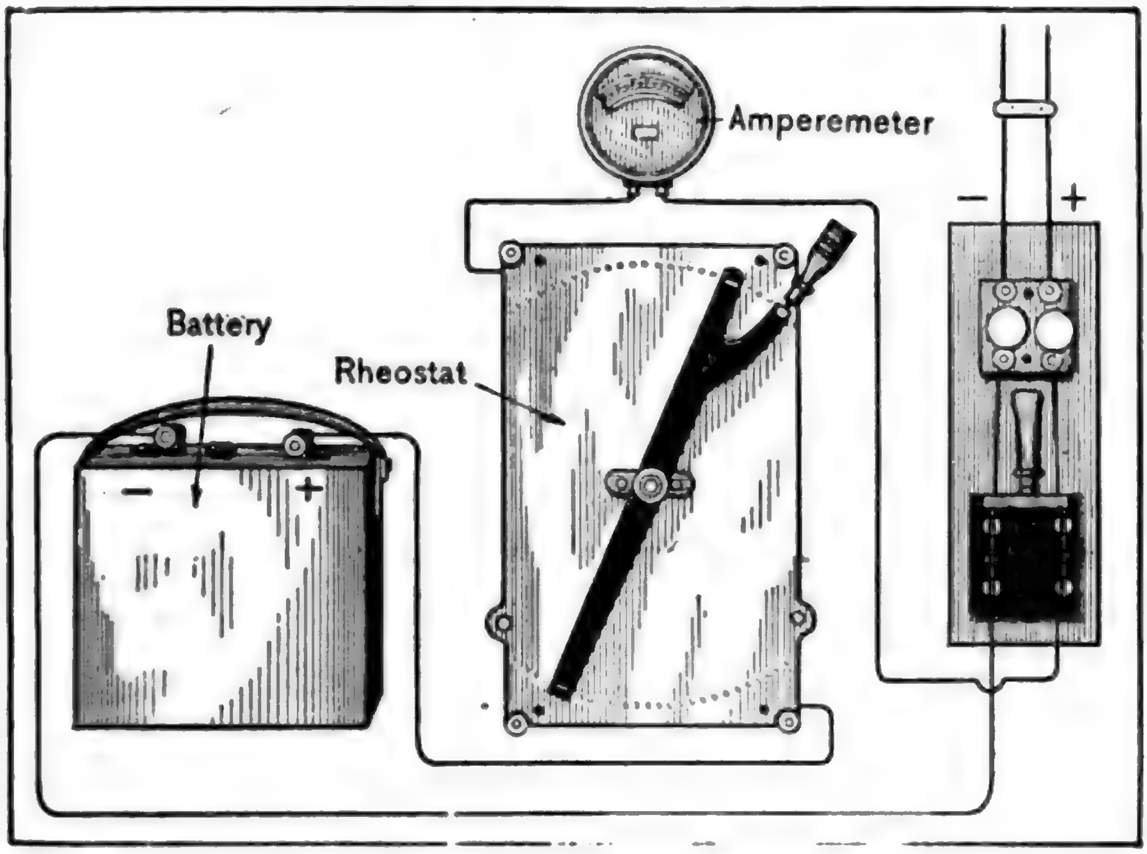


Fig. 512.—Direct-Current Battery-Charging Outfit, with Rheostat in Line Between Battery and Main-Line Switch.

A direct current of either 110 or 220 volts used over short distances, either 220 or 440 volts on three-wire circuits over long distances, alternating current at a constant potential, usually 110 volts, and in various polyphase systems. It might be stated that in the majority of instances house and garage lighting circuits furnish direct current of 110 volts.

Mercury Rectifier Bulb.—One of the most commonly used rectifying means is the mercury arc bulb. This device is a large glass tube of peculiar shape, as shown at Fig. 514, which contains a quantity of mercury in the base. On either side of this lower portion two arms of the glass bulbs extend outwardly, these being formed at their extremities into graphite terminals or anodes, indicated as A and A-1 in the diagram at Fig. 515. The current from the auto transformer is then attached one to each side. The base forms the cathode or mercury terminal for

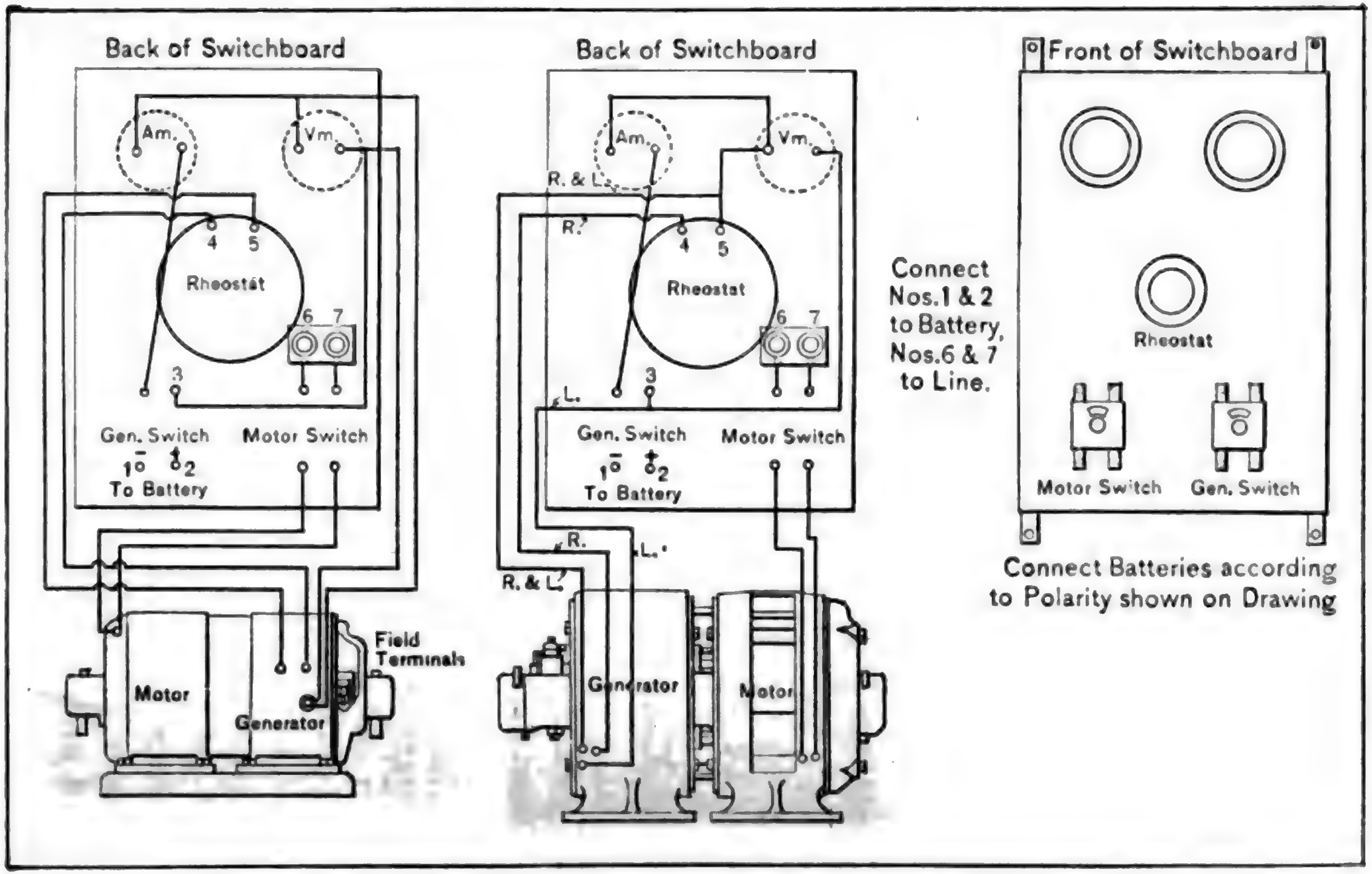

Back of Switchboard
Am.
Vm.
4
5
Rheostat
6
7
3
Gen. Switch
Motor Switch
1
2
To Battery
Motor
Generator
Field Terminals
Back of Switchboard
Am.
Vm.
R. & L.
R.
4
5
Rheostat
6
7
3
L.
Gen. Switch
Motor Switch
1
2
To Battery
R.
L.
R. & L.
Generator
Motor
Connect Nos. 1 & 2 to Battery, Nos. 6 & 7 to Line.
Front of Switchboard
Rheostat
Motor Switch
Gen. Switch
Connect Batteries according to Polarity shown on Drawing

Fig. 512A.—How to Wire Rotary Converter Charging Outfit, with Ammeter Rheostat and Voltmeter, Showing Front and Rear of Switchboard.

the negative wires. The theory of this action is somewhat complicated, but may be explained simply without going too much into detail. The interior of the tube is in a condition of partial vacuum, and while the mercury is in a state of excitation a vapor is supplied. This condition can be kept up only as long as there is a current flowing toward the negative. If the direction of the current be reversed, so that the formerly negative pole becomes a positive, the current ceases to flow, as in order to pass in the opposite direction it would require the formation of a new cathode element. Therefore, the flow is always toward one electrode, which is kept excited by it. A tube of this nature would cease to operate on alternating-current voltage after half a cycle if some means were not provided to maintain a flow continuously toward the negative electrode.

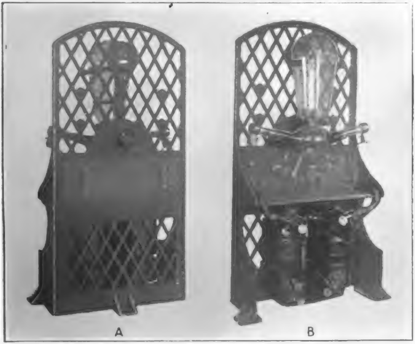


Fig. 513.—Westinghouse Mercury Arc Rectifier. A Shows the Front View. B Shows Rear of Panel Showing Bulb.

In the General Electric rectifier tube there are two anodes and one cathode. Each of the former is connected to a separate side of the alternating current supply and also through reactances to one side of the load and the cathode to the other. As the current alternates, first one anode and then the other becomes positive, and there is a continuous flow toward the mercury cathode, thence through the load (in this case the battery to be charged), and back to the opposite side of the supply through a reactance. At each reversal the latter discharges, thus maintaining the arc until the voltage reaches the value required to maintain the current against the counter E.M.F. and also reducing the fluctuations in the direct current. In this way a true continuous flow is obtained, with very small loss in transformation. A small electrode connected to one side of the alternating circuit is used for starting the arc. A slight tilting of the tube makes a mercury bridge between the terminal and draws an arc as soon as the tube is turned to a vertical position. The ordinary form used for vehicle batteries has a maximum current capacity of 30 amperes for charging the lead plate type, and a larger form, intended for use with Edison batteries, yields up to a limit of 50 amperes.

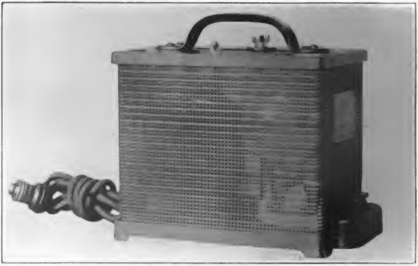


Fig. 513C.—Small Rectifier for Charging Storage Batteries of Starting and Ignition Systems of Gasoline Automobiles.

When batteries are to be charged from a direct current it is possible to use a rheostat to regulate the voltage at the terminals. The construction of a rheostat is very simple, as it con-

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sists only of a group of high-resistance coils of wire mounted in insulating material, and having suitable connections with segments on the base plate, upon which is mounted the operating arm that makes the contact.

Water Resistance for Discharging.—A water resistance is easily constructed by using a small wooden tub or half barrel. Two sheet-lead plates are suspended from wood sticks resting on top of the tub, the supports being movable to bring the lead plates closer together or separate them, as desired. A wire is

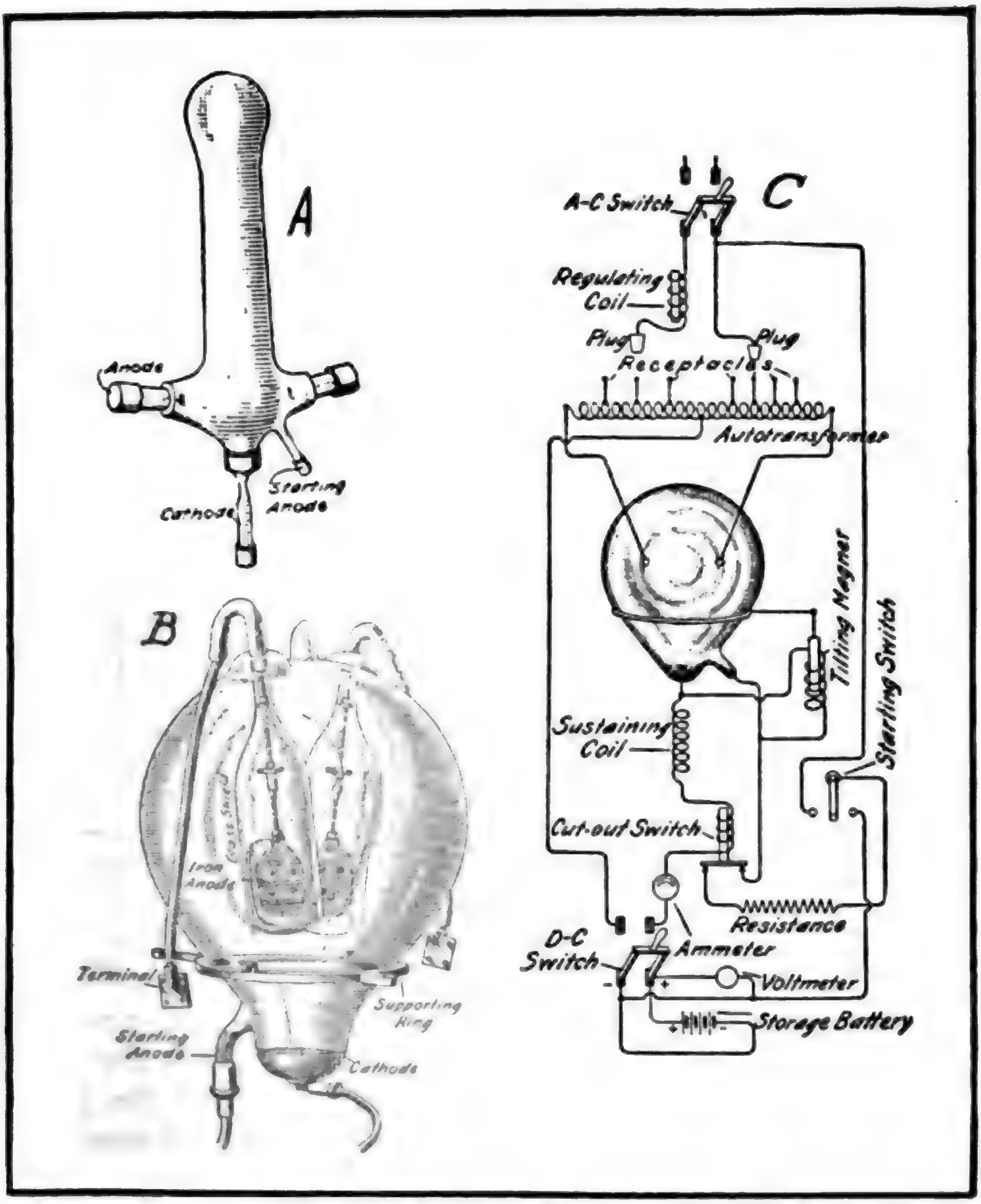
A
Anode
Cathode
Starting Anode
B
Glass Shield
Iron Anode
Terminal
Supporting Ring
Starting Anode
Cathode
C
A-C Switch
Regulating Coil
Plug
Plug
Receptacles
Autotransformer
Tilting Magnet
Starting Switch
Sustaining Coil
Cut-out Switch
Resistance
D-C Switch
Ammeter
Voltmeter
Storage Battery

Fig. 514.—Mercury Rectifier Bulbs and Methods of Wiring to Charge Storage Battery from Alternating-Current Mains.

brought from the battery, as shown in Fig. 516, to one side of the switch, then to one of the plates in the water resistance, then from the other plate of the water resistance to an ammeter; to the other side of the switch and from there to the opposite pole of the battery. Such a resistance is used for making a test discharge of a vehicle battery; it would not be a very practical way of charging batteries because of the great absorption of current by the water. Before starting a discharge, care should be taken to have the lead plates and wires separated. The tub can then be filled with clean water and the switch closed. A small quantity of electrolyte should then be poured in the water, a very little at a time, until the ammeter shows that the proper amount of current is flowing. The farther apart the plates are, the greater the resistance. As more electrolyte is added, even if the plates are not disturbed, the resistance becomes less. Never let the plates touch each other.

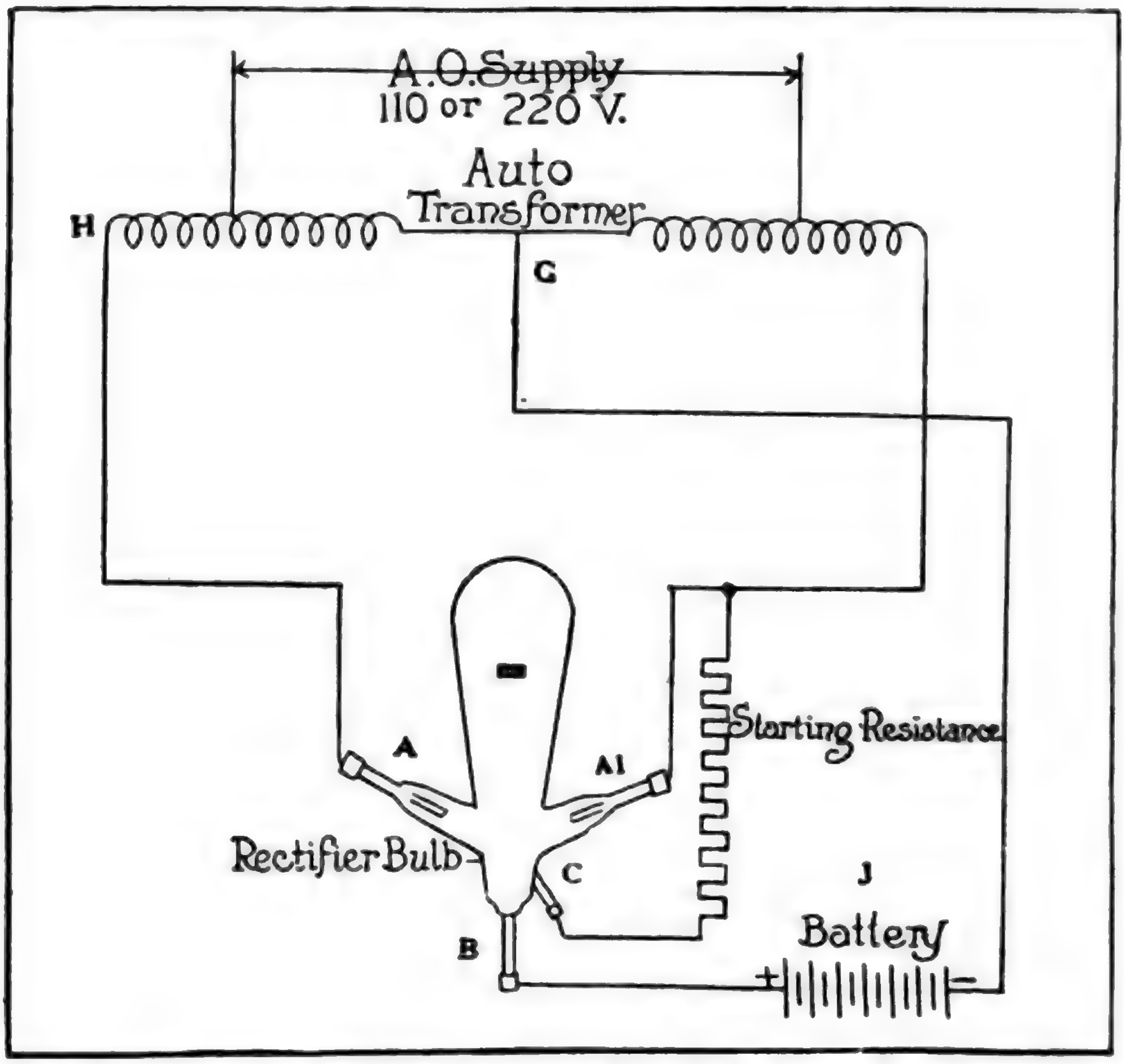

Fig. 515.—Wiring Diagram Defining Use of Mercury Arc Rectifiers.

Charging Vehicle Batteries of Lead-Plate Type.—The following extracts on modern electric vehicle batteries are reproduced from an article by J. H. Tracy and with the permission of the Electric Storage Battery Company, who issue the complete discussion in their Bulletin No. 156. These instructions do not apply to all types of lead-plate batteries, however, but refer to the latest vehicle types made by this company.

"To the user of lead acid storage batteries in self-propelled vehicles, the steady improvement of recent years is hardly

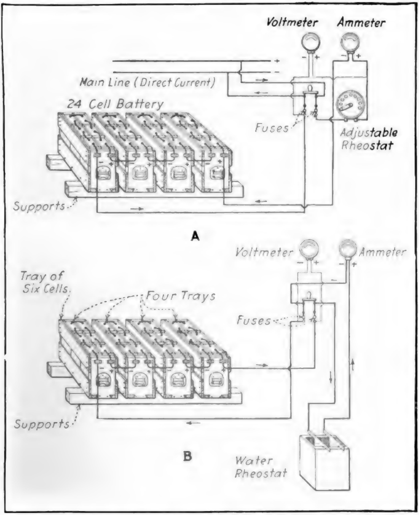
Voltmeter
Ammeter
Main Line (Direct Current)
24 Cell Battery
Fuses
Adjustable Rheostat
Supports
A
Voltmeter
Ammeter
Tray of Six Cells
Four Trays
Fuses
Supports
B
Water Rheostat

Fig. 516.—Method of Charging 24-Cell Vehicle Battery at A. How Water Rheostat is Used in Making Test Discharge Outlined at B.

noticeable to the eye, although there has been an increase in the watt-hour capacity of the battery per unit of space and weight, and also in the serviceable life of the battery. There has also been a marked advance in the permissible rates of charge and discharge, which has added so much to the flexibility of operation as to permit the use of much smaller batteries than would have been considered a few years ago in the same service. The following article explains the permissible rates of discharge and the behavior of batteries under operating conditions which a few years ago were considered prohibitive:

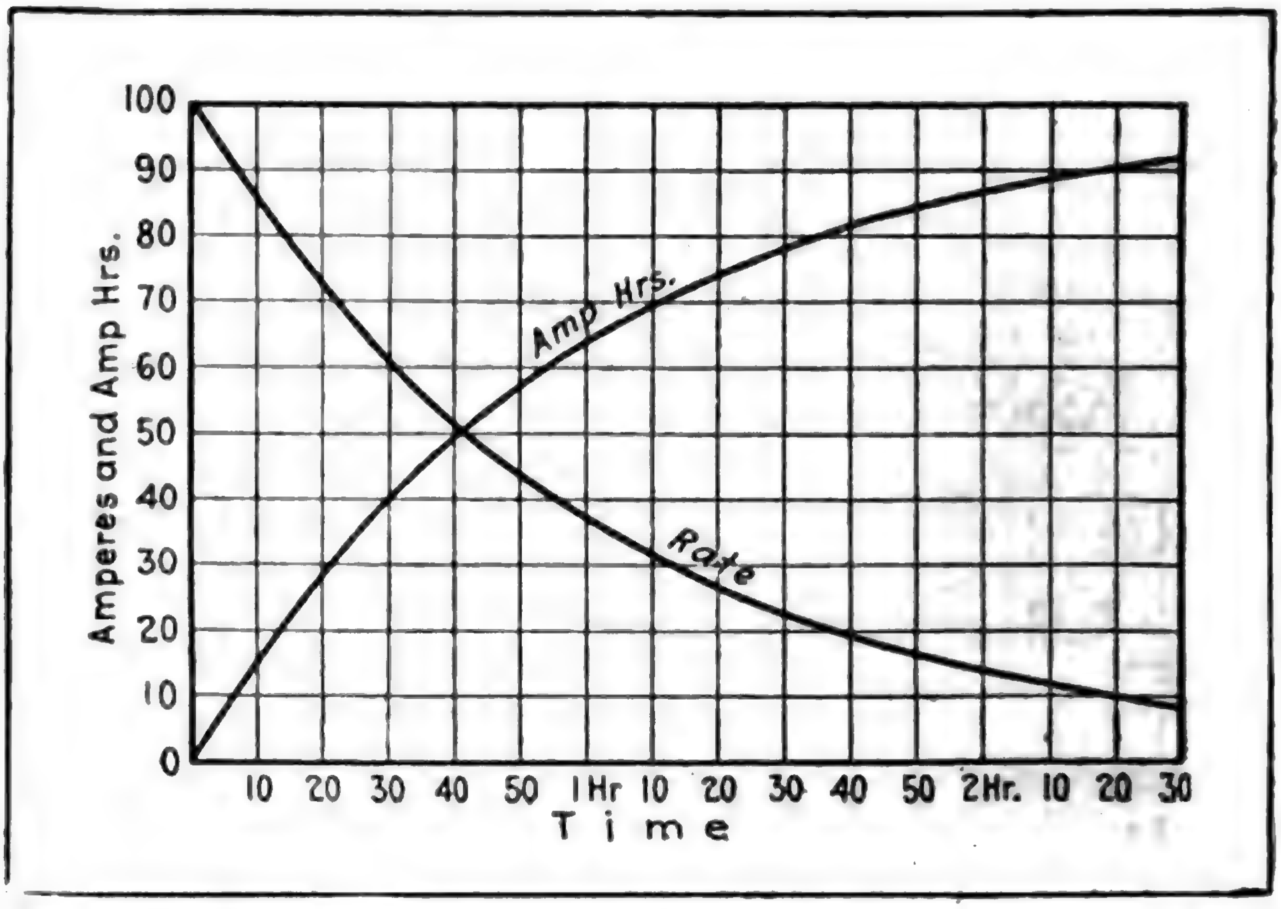

Fig. 517.—Theoretical Variation in Charging Rate When the Rate in Amperes Equals the Ampere-Hours Out of the Battery.

"It can be safely said that high rates of discharge are in no way detrimental to modern lead battery plates. Batteries of the vehicle type are in regular operation under conditions in which practically all their work is done at rates which would empty the battery in ten minutes, and the same batteries would be sold to operate at the three-minute rate if there were a commercial demand for such operation. For such high rates of discharge extra heavy terminals are provided to carry the current, no other changes being required.

"It is well known that when discharged continuously at constant rate the available ampere-hour capacity of a battery is

TABLE I—CHARGING RATES

Ampere-Hours Discharged	Time Available until next Adjustment of Charging Current.							
	¼ hour	½ hour	¾ hour	1 hour	1¼ hours	1½ hours	1¾ hours	2 hours
	Amperes	Amperes	Amperes	Amperes	Amperes	Amperes	Amperes	Amperes
10	8	6	5	5	4	4	3	3
20	16	13	11	10	9	8	7	6
30	24	20	17	15	13	12	11	10
40	32	26	23	20	18	16	14	13
50	40	33	28	25	22	20	18	16
60	48	40	34	30	26	24	22	20
70	56	46	40	35	31	28	25	23
80	64	53	45	40	35	32	29	27
90	72	60	51	45	40	36	33	30
100	80	66	57	50	44	40	36	33
110	88	73	63	55	49	44	40	37
120	96	80	68	60	53	48	43	40
130	104	87	74	65	58	52	47	43
140	112	93	80	70	62	56	51	47
150	120	100	86	75	67	60	54	50
160	128	106	91	80	71	64	58	53
170	136	113	97	85	75	68	62	57
180	144	120	103	90	80	72	65	60
190	152	127	108	95	84	76	69	63
200	160	133	114	100	89	80	73	67
210	168	140	120	105	93	84	76	70
220	176	147	126	110	98	88	80	73
230	184	153	131	115	102	92	84	77
240	192	160	137	120	106	96	87	80
250	200	107	143	125	111	100	91	83

EXPLANATION.—In the left-hand column find the figure nearest to the ampere-hours discharged from the battery; follow across to the column headed by the available time. The figure at this intersection is the current to be used.

EXAMPLE.—Ampere-hour meter reading, 103 ampere-hours discharged; time available for boosting, one hour. Start at 100 in the left-hand column; follow across to the column headed 1 hour and find 50, which is the current to be used.

Fig. 518.—Table of Charging Rates.

a function of the rate of discharge, the available capacity being lower at the higher rates. This reduction in available capacity at the higher rates of discharge is due to depletion of the acid in the pores of the plates. The rate of this depletion is the difference between the rate of absorption by the plates of the acid that is in the pores of the plates and the rate at which this acid is renewed by diffusion with the other acid in the cell. It is the limit of this available acid that limits the capacity of the battery at high rates of discharge, and not any limitation in the plates themselves. It is, therefore, impossible to damage the plates by overdischarge at high discharge rates. In fact, very low rates of discharge should receive more careful consideration than very high rates.

"In general, a battery may be charged at any time when a charge will be useful, and at any rate which will not cause the temperature of the battery to exceed 110 degrees F. and which will not cause the cells to gas freely except at low rates of charge. If these conditions can be watched, no further directions or limitations need to be considered. As it is not always possible to watch these conditions, several methods of charging have been worked out which reduce the amount of attendance required while charging, and which permit the selection of the most economical way to charge the battery under any particular set of local conditions, while assuring that the above limitations will not be exceeded."

Maximum Permissible Rate.—A general rule for determining permissible rate of charging a battery is: The charging rate in amperes must never exceed the ampere-hours out of the battery. Any method of charging that keeps the charging current within this limit will not overheat the battery or cause it to gas. In applying this rule it is not necessary to reduce the charging rate below the "finishing" rate recommended by the battery manufacturers. If an ampere-hour meter is used on the vehicle, so arranged as to indicate the ampere-hours out of the battery, it also indicates at all times the maximum permissible charging rate. It will be noted that the maximum charging rates are no longer a function of the size of the battery or its relative state of discharge, but depend only on the actual state of discharge. The curve in Fig. 517 shows in percentage the theoretical variation in charging rate and also in state of charge if a battery were charged strictly in accordance with this rule, and this represents the method by which a battery may be safely charged in a minimum time in regular operation.

It is evident that very wide latitude for proper charging is offered from which to select the best way to charge a battery under any given local conditions. If the vehicle is equipped with an ampere-hour meter the readings of this meter may be taken as the basis for selecting a charging rate which may be used for a particular length of time, so that at the end of that time the charging rate will be at the maximum permissible rate, at which time the rate should, of course, be reduced. It follows from the general rule for charging that, if $R =$ permissible charging rate, $D =$ ampere-hours out of the battery at the start of the charge (reading of the ampere-hour meter) and $T =$ times in hours until the current can be adjusted, then $R = D \div (+ T) =$ maximum permissible charging rate for T hours, and at the end of T hours the charging rate will equal the reading of the ampere-hour meter. This value can again be divided by $1 + T$ for the new charging rate, and so on until the charge can be finished at the finishing rate. If it is desired to charge the battery rapidly, the time T should be taken as short as possible. For convenience Table I, given in Fig. 518, calculated from this formula, is given. This table is of use not only in the charging-room, but also for the determination of the best manner for charging vehicles under any contemplated conditions and for the selection ot charging equipment to meet the requirements of these conditions.

Ampere-hour Meter Indications as Basis for Charging.—It should be carefully noted that if an ampere-hour meter is made the basis for charging a battery, care must be taken to be sure that the meter indicates as nearly as possible the real state of charge of the battery. An accurate record of the ampere-hours discharge from a battery does not give an accurate measure of the ampere-hours necessary to fully recharge it, for there are certain variable losses in the battery which the ampere-hour meter cannot measure. In fact, there is no accurate way to predetermine exactly how many ampere-hours charge may be necessary to fully charge a battery, nor is it necessary in ordinary service that the battery be really completely recharged daily. An ordinary clock is not an accurate instrument for measuring time, yet if it is set correctly occasionally it is sufficiently accurate for ordinary purposes. It is the same with an ampere-hour meter. It is necessary that a battery be fully charged occasionally, say, once a week, if the battery is subjected to hard daily use, as on a commercial truck, and this furnishes an opportunity to set the ampere-hour meter.

Fully Charged Battery.—A battery is fully charged only when all the sulphate has been driven out of the plates into the electrolyte, and this is most easily indicated by the specific gravity of the electrolyte. As long as sulphate is being thrown out of the plates into the electrolyte during charge, the specific gravity of the latter must continue to rise, and when the rise stops the battery is fully charged. Most battery manufacturers recommend that a battery be given such a charge (called an equalizing charge), regardless of the indication of the ampere-hour meter, once a week or once in two weeks. When it is known that the battery is full, the charge is discontinued and then the meter is set to indicate a full battery, and the meter is then a sufficiently accurate indicator of the state of battery charge to be used for a week or two weeks until another equalizing charge is given the battery, when the meter should again be set.

Ampere-hour meters require cleaning and regulation at intervals as does a clock, and if they are treated in this manner they are of great assistance in the proper handling of a battery. These meters are frequently furnished with a contact-making device, so arranged as to interrupt the charging circuit when the meter indicates that the battery is fully charged, and this is a valuable protection against unnecessary charging and gassing of the battery during ordinary operation. This tripping device should, of course, be disconnected during the equalizing charge.

The points to be especially emphasized in connection with the charge are:

First—On regular charges keep the rates as low as practical and cut off the current promptly. It is preferable to cut off a little too soon rather than to run too long where there is any question.

Second—Overcharges must be given at stated intervals and continued to complete maximum. They should be cut off at the proper point, but when in doubt it is safer to run too long, rather than to cut off too soon.

Third—Do not limit the charge by fixed voltage.

Fourth—Keep the temperature within safe limits.

Fifth—Keep naked flames away from cells while charging, as the gas given off is inflammable. Always see that gas vents are clear before charging.

Westinghouse Charging Equipment.—With the rapid development of reliable electric vehicles and the rapidly extending use of same, a corresponding and incessant demand has risen for apparatus to charge the storage batteries. The service requirements are very diversified and the line of apparatus to fulfill them effectively must be very comprehensive. The battery charging equipments must be capacities such that a single car may be cared for efficiently in an isolated private garage, and that many cars housed in a public or large private garage may be charged at any and all hours methodically, promptly, efficiently and cheaply. The electrical energy available at the service mains may be continuous current, either two or three wire, 100 volts or 220 volts, or it may be alternating current of one, two or three phase and of any commercial voltage.

The Westinghouse Electric and Manufacturing Co. early recognized the influence on the extensive use of electric vehicles by having available battery charging equipments that adequately serve this variety of purposes. Therefore, a complete line of battery charging apparatus has been developed for this service comprising rheostats, mercury arc rectifiers, motor-generator sets, and switchboards.

If continuous current of suitable potential is available the battery may be charged most efficiently and conveniently by the use of a simple rheostat connected in series therewith and mounted on the floor, wall, or rear of a switchboard. In case the potential of the service mains is high, relative to that required to charge the battery, it will be more economical to use a motor-generator set.

When alternating current only is available, it is essential to transform this into continuous current through a rectifier or some rotating apparatus such as a motor-generator set. The selection of the piece of apparatus is influenced by the number of batteries to be charged and the potential across their terminals; in general, a rectifier is preferable for single cars, and a motor-generator set for several cars, particularly if the batteries are of different type and vary widely in number.

For a large garage in which cars must be charged at all hours, but mainly at night, it often proves to be economical to use a motor-generator during "off peak" only and a rectifier alone during the other hours.

In the Westinghouse motor-generator sets the generators have been designed so that the voltage of the continuous current machine may be adjusted practically anywhere between the limits of 60 volts and 125 volts by manipulating a field rheostat. Hence, the operator may adjust the terminal voltage to that required

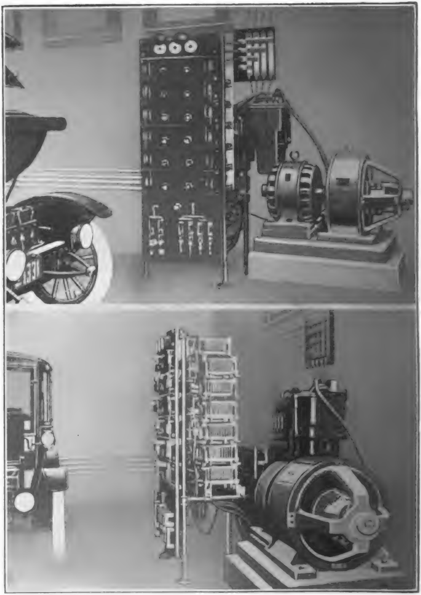

Fig. 519.—Westinghouse Rotary Converter for Charging Electric Vehicle Batteries.

by the batteries on charge, and reduce to a very small minimum the energy dissipated as heat in the rheostats.

The switchboards are designed so as to secure simplicity of arrangement. They are built up of Sectional Type Panels, which

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construction makes a very flexible line in that switchboards can be assembled for controlling any combination of power supply and batteries and additions can be made readily. These switchboards are assembled usually with the meter section at the top, the charging sections immediately below, and the power control section at the bottom. The number of sections per panel is limited by the height permitted by ease in operation. When more charging circuits are desired than can be accommodated on one panel, the remaining sections are made into additional panels.

The meter sections are usually equipped with a battery ammeter, a voltmeter which may be "plugged" in on any circuit, and, when required, a generator ammeter. The battery ammeter is protected by a fuse mounted on the front of the section. The charging sections are built usually for controlling the two battery circuits. Each circuit is supplied with a two-pole fused knife switch or a single-pole automatic overload circuit-breaker (as desired), a rheostat hand wheel, an ammeter switch, a voltmeter receptacle, and card holder for circuit designation. Charging sections equipped with circuit-breakers are usually supplied with automatic protection against reverse current. When desired, protection against over-voltage or both reverse current and over-voltage can be provided by means of suitable relays.

Power control sections are supplied for direct current lines of the two or three wire type, or for the control of motor-generator sets. Battery charging rheostats are built of cast iron grids, and are designed for charging either lead or alkaline batteries of any specified number and type of cells. In special cases rheostats for charging either lead or alkaline batteries may be supplied. Rheostats can be furnished for switchboard or separate mounting.

CHAPTER XV

DRIVING AND MAINTENANCE OF ELECTRIC TRUCKS

Directions for Operating and Maintaining Couple-Gear Trucks—Starting—Running—Use of Shunt—Controller—Tires—Lubrication—Care of Commutator — Replacement of Bearings — Adjustment — To Remove Armature—To Remove a Wheel—To Disassemble the Wheel —Assembling—Adjusting Evener—A Few Things Not to Do—Care of Couple-Gear Battery—Charging—Regular Charge—Care of Battery—Couple-Gear Gas—Electric Instructions—To Operate Electric Brake—Instructions for the Care of Four-Wheel Internal Drive Trucks — Battery — Battery Compartment — Motors — Controller—Steering Rod Connections—Internal Gear Drive Instructions—Instructions for Both Models—Adjustment of Axle Bearings—Instructions for Walker Truck Drivers—Starting—Stopping Controller—Traction — Speed — Instruction for Garage Foremen — Weekly and Monthly Inspection—Instructions for Care of Walker Chassis—Motor Housing—Pinch Bolts—Wheel Alignment—Care of Motor Parts—Proper Handling—Ampere Hour Meter—Current Consumption—To Remove a Rear Wheel—Lubrication—Winter Care.

DIRECTIONS FOR OPERATING AND MAINTAINING COUPLE-GEAR TRUCKS

Starting.—Release the brakes. Right pedal operates brakes on front wheels. The left pedal operates brakes on rear wheels. Close emergency switch by pulling lever up. This lever is on the front of the heelboard at the right of the controller. To move the truck forward, pull the small lever on the controller top toward you and move controller handle one notch at a time. Don't linger between points; always turn lever far enough to bring pointer opposite a number on the controller top.

Running.—Keep feet on brake and left hand on controller lever when running until thoroughly familiar with the truck and the handling of it. When leaving the truck, or in case the controller fails to operate (freezes), push down the emergency switch lever, thereby disconnecting the battery. Never reverse the power until truck has come to a full stop except to prevent serious accident.

To avoid skidding, when making a stop on slippery streets, apply both sets of brakes as hard as possible without sliding the wheels. If the wheels start to slide, the brakes must be released a trifle to allow them to revolve again. If the wheels slide against a wet car track, do not continue to cramp wheels but steer them in the opposite direction, pulling away from the rail and then crossing it more squarely. Never use the brakes unnecessarily.

When one motor is disconnected, use fourth speed on all heavy pulls, as first, second or third speed under this condition causes half of the battery to be discharged faster than the other half.

When descending long steep grades, both brakes should be used to avoid excessive heating of one set.

Operation.—Do not stop or slow up when it can be avoided except for rough places or for a heavy pull. More current is required to start the truck from a standstill than to keep it running when under way. Never use power where truck will coast. To save power, avoid hills and soft or rough roads, as much as possible, even though the other way is a little longer.

Do not use fifth speed on steep grades or heavy roads. The fourth speed is just as powerful as the fifth and works the battery and motors to better advantage on a heavy pull.

If the wheels spin, do not leave the current on an instant after it is found the truck does not move, as this will overload motors and may seriously injure armatures.

Use of Shunts.—"Couple-Gear" trucks are equipped with shunt for shunting the current around the motor fields, thereby increasing the speed of the armature. This shunt is brought into the circuit when controller is on fifth point and should not be used except on good roads or when its use does not cause excessive current consumption.

Controller.—Keep contacts clean with piece of cloth. Lubricate lightly with vaseline once each week. If contacts blister or get rough, the cause should be located. It may be due to a weak spring on the finger or improper adjustment of the spring. There is a set-screw and lock-nut on each finger to make this adjustment. After the cause of the trouble is removed, the contacts should be smoothed up with fine file and sandpaper.

Tires.—When tires show signs of giving out, an extra band with new tires on should be ordered, so when the tires do give out you will have one on hand to replace it.

Lubrication.—Keep the spring clips lubricated. Oil all moving parts of steering gear frequently. Give all grease cups a turn every morning. The grease cups on one side of the wheel knuckles feed to back wheel roller bearing. There are two roller bearings, one on each side of the wheel. These should be oiled once a week.

The gears should get sufficient oil from the motor bearings. There are two motor bearings, one on each end of the armature shaft. The wick feed of enclosed type requires filling once a week after they are well worn in.

When they are new they should be watched very closely and may require oil every day. The wicks should be changed every six months. To fill these bearings, pour oil in at the side and fill until they overflow, having a piece of waste at the bottom to catch the overflow.

At the opposite end of the armature from the commutator is a device that is termed the "evener." Its function is to divide the load evenly between the two pinions and to take up any inequalities in the gears. A very slight motion takes place here, but enough to require oil, so put a few drops in when oiling the motor bearings.

The wheels should be jacked up and carefully looked over once each week and motor bearings oiled. Inspect all bolts and nuts and see that everything is in normal condition.

Commutator.—Keep it clean, using cloth instead of waste, as the latter will leave lint on it that sometimes gets under the brushes causing an arc, which burns the commutator. Keep the brush-holders clean inside and out. Watch the carbons and do not let them wear down so far that the holder does not bring any pressure on them. If these are neglected, they will wear off in time and make a poor contact with the commutator, causing it to be burned and require turning off in a lathe.

In case the commutator does not wear smoothly, look to the brushes, and if they are all perfectly free in the holder, see whether the tension is the same on them as on the other motors. If these points are found to be all right and the commutator is very bad, take the armature out and have it turned off in a lathe. Occasionally a commutator can be brought back in shape again by sanding it off with 00 sandpaper; never use emery paper. A good commutator will get a blue polished surface, and that is what you want.

Bearings, Replacement of.—The motor bearings when properly lubricated wear from one to two years. They must not be allowed to wear enough to let the armature strike the pole pieces. The bushings only are needed to renew.

The wheel roller bearings can be taken out and replaced with new ones very easily. They should wear much longer than the motor bearings. The race rings that the roller bearings turn in are case hardened and can be taken out and replaced.

Adjustment.—The gears are properly adjusted when the truck leaves the factory and will only get out of adjustment from having the wheels taken apart or from natural wear of the wheel thrust collars, which are adjustable, one being the large slotted nut on the outside and the other being a round thread casting that either screws into the wheel or onto the knuckle. When the face of the front nut wears, it allows the wheel to pull away from the knuckle and as the motor remains stationary it will bring the back gear deeper in mesh with the pinion on the commutator end.

If the back collar wears, it will allow the wheel to run in closer to the knuckles, bringing the front gear deeper in mesh with the other pinion. If either one wears to any extent, it will cause the gears to become noisy.

This wear can be taken up by the adjusting nuts on each side of the wheel. The only difficult part is to learn which side is worn. There are two or three ways of doing this. In the first place, if the collars are worn the wheel will have an end play; force the wheel first in and then out. If there is more than $1/32$ inch play, there is too much.

One way to adjust it is to force the wheel against one collar and then turn it around a few times, noting the amount of noise; then force the wheel against the other collar and note the noise. Set the wheel in position that it will run the quietest.

Another way is to put your hand inside the evener box, getting hold of the end of the two pinion shafts, one at a time, and by moving the pinions you can tell which one has the most play: the one having the least play is in mesh the deeper of the two.

The most accurate method is to turn both the adjusting nuts back several threads. Pull the wheel out as far as possible, bringing the back gear up against one pinion, then turn the front adjusting nut up until it just touches the wheel; then push the wheel back as far as possible, bringing the front gear up against the other pinion. This will leave a space between the front nut and the wheel and will represent the amount of clearance of the two gears. Turn the nut up just half this distance and lock it, pull the wheel out against the nut and turn the back adjusting nut to the left until it tightens; then slack off one slot or about $\frac{1}{16}$ inch of a turn and lock there. This will leave one pinion just as deeply in mesh as the other, and that is what is wanted.

To Remove Armature.—Remove the hub cap and adjusting nut. Take out the machine bolts that pass through the two wheel discs. By means of special clamps furnished in tool equipment, pull the front disc out of the tire. This will expose the motor. Remove the cap screw and bolts in the motor frame, then pull the front half of the casting off, lift out the armature, bearings and all, and lay it across a box so that the bearings can hang down and avoid spilling oil.

To Remove a Wheel.—Raise the wheel about 2 inches off the floor and also the opposite wheel so as to leave the axle level. Disconnect the motor wires by loosening 4 hexagon head cap screws in receptacle and pull the plug down. Remove small set screws from back stub nut. Insert cast sleeve (in tool equipment) between axle fork and rear stub nut. Then back off the stub nut with large wrench provided. This will crowd motor stub knuckle and relieve the wheel. See that motor wires do not get caught in knuckle.

To Disassemble the Wheel.—After the wheel is off the truck, place it on jacks with rear stub downward. Remove the hub cap and adjusting nut and the machine bolts that hold the two wheel discs against the shoulders in the tire band. Remove front disc and gear ring, using pull bars and bolts provided. Both the disc and gear ring are tapped to take the pull bolts. The motor can then be raised from the wheel.

Assembling.—Assemble the wheel the same way it was taken apart, being sure that evener bars are parallel with each other and with armature shaft. When both gear rings are in place, then insert front disc and bolts. Then place wheel in vertical position and properly divide the gear and pinion clearance as previously instructed.

Adjusting Evener.—The mechanic will notice that the pinions are not rigidly connected to the armature. They are connected to the armature quite similar to the way a team of horses are connected to a wagon. They are hitched to an evener that allows one horse to drop a little behind the other, but each horse can pull half the load only.

The evener in the armature performs the same function for the two pinions that the evener does for the two horses. If one horse drops so far back that the evener strikes the wagon, the other horse must pull all the load. If the pinion is allowed to enter the gear with the evener shifted way to one side, then one pinion will do all the work, so the pinions should be entered into the gears with the evener set in the center so it will have a chance to work either way. It is not always possible to get it in the center, but it should be set as near the center as possible.

When the evener is set right, the cotter pins that pass through the ends of the pinion shaft will be opposite each other and in line with the armature shaft, and the key seats in pinion shafts will be in line and abutting each other.

After the evener is set right, the disc can be driven in, bringing the gears into mesh.

A Few Things Not to Do:

1. Do not neglect to carefully inspect wheels each week.
2. Do not fail to correctly adjust the evener when assembling wheel.
3. Do not reverse the power before the truck stops.
4. Do not fail to adjust the gears when they become noisy.
5. Do not use power on down grades when machine will coast.
6. Do not wait for tires to fall off before getting them repaired.
7. Do not allow carbon brushes to wear down too far or become tight in the holders.
8. Do not refuse to give a helping hand to stalled teams.

Care of Couple-Gear Battery.—Standard lead battery cell is composed of two groups of lead plates, one positive and one negative. These plates are separated from each other by wood and hard rubber separators; the plates and separators are called elements. The elements are contained in a hard rubber jar filled with a diluted solution of chemically pure sulphuric acid. This makes a complete cell. In a truck there are usually from 40 to 48 of these cells, all of the same size and capacity.

The larger trucks have larger cells but about the same number. All cells are of equal voltage, about 2 volts the capacity of a cell or ampere-hour rating, depending upon the number of plates in each cell. Each cell has a positive and negative pole. The cells are connected together with a lead strap or bolt connector, the positive or one cell to the negative of the next. This is when they are connected in series and is the usual way. The ampere-hour capacity of 40 cells in series is not greater than the capacity of one of the cells, but the 40 cells will be of 40 times the voltage of one cell.

A battery is analogous to a barrel of water. The barrel contains just so many quarts of water and the battery so many amperes of electricity. If the barrel contains 252 quarts of water and this is drawn off at the rate of 63 quarts an hour, the barrel will be emptied in four hours.

A 44-cell, 19-plate battery such as is used in "Couple-Gear" truck contains 252 ampere-hours. If this is used at the rate of 63 amperes, the four hours normal discharge rate, the battery will be exhausted to the normal limit in four hours. If only half the hourly quantity is used (31½ ampere-hours), the discharge will, of course, be extended over double the time, or eight hours, and so on. An ampere-hour means one ampere flowing continuously for one hour.

The "volt" is the unit of pressure, analogous to the weight of water forcing a stream through a tap at the bottom of the barrel. So many gallons of water at so much pressure will do so much work. Similarly so many amperes of electricity at such a voltage will produce so much energy. This energy is expressed in "watts" and is calculated by multiplying the volts by the amperes. As previously stated, to exert one horsepower, an energy of 746 watts is required. It does not matter what may be the real relative proportions of voltage or amperes, the result will be the same, whether there are 10 amperes at 100 volts or 100 amperes at 10 volts. For the sake of convenience, in working large figures, one thousand watts is called one kilowatt.

The voltage of the storage battery may be figured at 2 volts per cell, or a total of 88 volts for a 44-cell battery, which is about what the voltmeter on the truck will show when the battery is fully charged and is being discharged at about 4-hour rate, possibly a little more just at first. The voltage falls as battery is discharged, just as the pressure of the water in the barrel is drawn off and the weight lessened. The ordinary routine of caring for a storage battery requires no great amount of skill or expert knowledge. All that is necessary is to use common sense and adhere strictly to every rule laid down for guidance in the instruction book issued by the battery company. Many batteries have been ruined by carelessness in this respect. Stick to the rules and if conditions arise that cannot be handled, do not experiment, but call in a battery expert, preferably one whose specialty is the battery you have.

Charging.—No difficulty need be experienced by charging the battery if instructions are followed closely, but any carelessness or attempts to short cuts or "original" methods are sure to lead to unsatisfactory results in the work performed by the truck and later to expense in putting battery back into shape.

The charging current in all cases must be direct, never alternating. If alternating current is the only source of supply, then some method must be employed (motor, generator or rectifier) to convert same to direct current. The voltage necessary to charge battery depends on the number of cells in the battery. About 2.7 is necessary to each cell. A 110-volt line will charge a 42-cell battery.

The positive terminal of the battery must be connected to the positive terminal of the charging circuit and the negative to the negative, so that the battery will be charged in the right direction. If charged in the reverse or wrong direction, the battery will be seriously injured, if not ruined.

See that the controller handle is in the "off" position and remove the reverse handle. Place the emergency switch "in" as when running. Make sure that the current is turned off at the charging panel or switchboard and insert the charging plug in the receptacle at the rear of the truck under the body. Be sure the plug is inserted as far as it will go. The lamps on the vehicle should be turned off while charging.

Commence the charge and complete it at the rates specified for such sized battery in the instruction books furnished with each battery and applying to it. Different makes of batteries should be handled in accordance with the instructions issued by the companies making them and we recommend that their instructions be very closely followed. When charging keep the battery ventilated as thoroughly as possible by opening the battery compartment. The following instructions may be followed in charging any make of storage battery having pasted lead plates, until the regular instructions on that particular battery can be obtained, as practically the only points on which the different instructions vary is on the charging rates.

Regular Charge.—On beginning of charge, the rheostat handle should be turned so that all resistance is in the circuit; then close switch connecting battery to the main and turn the rheostat handle until the ammeter shows a proper rate of current flow (see following table). In regular service, the battery should commence to charge at a rate not exceeding the "starting" rate given in the accompanying table and continued until the voltage equals 2.5 to 2.6 per cell, about 112 volts in a 44-cell battery. When this value is reached, the current should then be reduced to the "finishing" rate, as shown in following table, and charge continued until voltage ceases to rise again.

About once every two weeks, however, the charge should be prolonged and continued for two to four hours at the low rate after the gravity of electrolyte has stopped rising, but never raising the temperature above 100° F.

CHARGING TABLE

No. of plates per cell		Rate of charging in amperes		Charging rate for wet plates	
		Start	Finish	Start	Finish
7	For thick plate	16	5-5½	..	..
9		22	7	15	8
11		28	9	17	10
13		34	11	20	12
15		40	12	24	14
17		45	14	27	16
19		50	16	30	18
21		56	17½	34	20

As soon as the charge is stopped, the voltage of the battery will drop one-third of a volt per cell. Never continue the battery on charge at less than the "finished" rate as per table. The final voltage of the battery will vary according to the temperature of the battery and the age of the plates.

A new battery will have a higher final voltage than an old one under the same temperature conditions, and both old and new batteries will read higher with the temperature low than with it comparatively high; so, in view of the final voltage being chargeable, a fixed voltage must not be considered in determining the end of charge, but rather a maximum voltage, this being determined by noting when the voltage, as the end of the charge approached, stops rising.

The voltage per cell is determined by dividing the total voltage of the battery as shown by the voltmeter by the number of cells. Thus, in a battery of 24 cells, when the voltmeter shows 60 volts, the voltage per cell is 2.5 volts.

Great care must be taken to fully charge the battery but not to excessively overcharge, especially at the higher rate, as deterioration of the plates will result. If for any reason, such as bringing up of low cells, an overcharge is necessary, then the "finishing" rate should be used. A very noticeable increase in the temperature of the cells is an indication of excessive overcharge.

The temperature of a battery must not be allowed to exceed 100° F., the cells near center of battery being used as a guide. If the temperature is found to be running up toward the safe limit (100° F.), the charge should be stopped for a while, allowing the battery to cool.

After completing the charge and before disconnecting the battery from the switchboard, always turn the rheostat handle back before opening the battery switch. Voltage readings should be taken only when the battery is charging or discharging. Readings taken when the battery is idle are of no value.

Care of Battery.—Add distilled water to the electrolyte to replace the loss by evaporation. In average service a battery requires water about once a week. In hot weather, sometimes semi-weekly. If the acid strength is right when the battery leaves the factory, and providing there was no loss by spilling in shipment, the electrolyte will need no more acid added to it until the battery requires cleaning. Never add acid without first giving a long overcharge at a low rate to be sure that all acid has been driven from the plates into the electrolyte.

Charging Panel for One Battery.—Consists of one ammeter with 100-ampere scale, one voltmeter with 150-volt scale, one 2-pole single-throw switch, and fuses or circuit-breaker mounted on slate or marble board. A rheostat must be used in connection with the charging panel. It consists of resistance coils or iron grids so connected that the resistance can be regulated or entirely disconnected from the circuit. The rheostat is connected in series with the battery and is used to regulate the ampere flow.

A water rheostat can be used temporarily. This consists of a receptacle made of non-conducting material, such as barrel, wood tub, or earthen jar. This receptacle is partly filled with salt water. One charging wire is cut and a metal plate attached to each end. These plates are dropped into the salt water and the flow of current regulated by the separation of the plates.

COUPLE-GEAR GAS ELECTRIC INSTRUCTIONS

To Start Engine.—To start engine, open the valve in the gasoline pipe just under the tank. Retard the spark by pulling the round brass lever located at the left of the crank as far out as it will go—that is, until it catches. The ignition switch is on the coil on the dashboard. Start on the battery side. In cranking the engine, be a little careful as we set the crank pretty well in advance so that the engines sometimes kick back a little. As soon as the engine starts, release the lever which automatically advances the spark.

If you have any trouble in starting, it might be because the batteries have weakened in shipment. A little gasoline injected through the petcock in each cylinder will assist materially in starting. This is very seldom necessary except in very cold weather.

When engine is equipped with Stromberg carburetor, it can be primed by shoving in a small wire just below the retard lever. This closes the air inlets and causes the piston to draw gasoline from the carburetor into the combustion chamber. Two turns of the crank should be sufficient. Then open air inlets and press button on coil, which should start the engine.

The control of the engine is entirely by foot throttle, which is closed by a spring, except when the driver opens it. The spark advance is fixed, and is retarded only when cranking engine.

When shipped, the makers drain the gasoline tank and radiators. The drain of the radiator is a plug underneath it. The drain of the pump is a petcock located at the lower side of it. Rayfield and Stromberg carburetors are equipped with water circulating system, the Schebler with hot-air pipes.

Starting the Truck.—The controller has two levers. The left-hand is the reverse, the right-hand the speed lever. The controller has six speeds forward and six speeds reverse. On the

1st and 2nd speed the motors are in series with resistance. On the 3rd the motors are in series without resistance. On the 4th the motors are in parallel with resistance. On the 5th in parallel without resistance. On the 6th they are in parallel with shunted fields.

For running forward, put reverse lever in position so that pointer is at the letter "F" on the controller top. For running backward, the pointer should be at "R" on controller top. When reverse lever is so placed, the various speeds of the machine are secured by bringing the pointer on the speed control lever to the various speed points as indicated on controller top.

To Operate Electric Brake.—When running forward: 1st. Bring speed-control lever pointer to off position. 2nd. Move reverse lever pointer from "F" to the left. The 1st, 2nd and 3rd points are braking points. The other points should not be used in braking under forward motion.

When moving backward: 1st. Bring speed-control lever pointer to off position. 2nd. Move reverse lever points from "R" to the left onto 1st, 2nd or 3rd point as is necessary. The shunt speed should be used only when road conditions are favorable and current consumption not over 100 amperes.

In starting, the driver usually turns the current on to the full speed and then raises the voltage with the foot throttle, and one seldom turns the controller off in regular operation except when coming to a full stop, and not even then when it is only a short stop, such as in the traffic. In climbing grades, or for heavy pulls, if the engine slows up or labors unduly, cut in the resistance in the generator fields. This is done by turning the handle on the rheostat. If this does not take you up the hill, drop the controller back to the series position, third notch, and you can then regulate your rheostat according to the severity of the grades. When in series, it is all right to carry a fairly high voltage, 150 for a long pull. If only a short grade, it will even stand higher, as the motors only get half the voltage. The dynamo will stand 150 volts for an hour and higher voltage for a short period. It is not advisable to give the motors more than 125 in practice.

The dynamo has ring oil bearings. There is a brass cup on each for filling and an overflow through a petcock, which must be opened when filling. These should be filled until they overflow each week. You will find a slide in the pan at the side of the dynamo, that will let you see the glass in the front bearings, so that you can tell when the oil is low. The commutator of the generator should be cleaned with a cloth while it is turned over slowly about once a week, and it would be advisable when the dynamo is new to take the brushes out and sand them off lightly with some 00 sandpaper to remove the copper that will have collected. This is not necessary after the commutator becomes polished.

INSTRUCTIONS FOR THE CARE OF FOUR-WHEEL INTERNAL GEAR DRIVE TRUCKS

(Commercial Truck Co. of America)

Battery.—Battery should be cared for in accordance with instructions issued by the manufacturer of the particular battery installed and considered at length in preceding chapter.

Battery Compartment.—When truck is equipped with Edison battery the battery compartment is built with removable strips in the floor of the compartment under the center of each tray and on the rear of each section near the top. These should be removed in the summer to give proper ventilation and should be in place in the winter.

Motors.—The motors should at all times be kept clean and free from water or oil. The commutator is in best condition when it has a dark red or purple polish, and when in this condition needs no attention. If it becomes black or burned from any cause it should be cleaned with a fine grade of sandpaper. It should always be kept clean and free from gummy or gritty substance. The carbon brushes should be renewed before they are completely worn out. If brushes are allowed to become too short the commutator is apt to get burned. When new brushes are put in they should be fitted to commutator and pigtail connections securely fastened to the brush holder.

Controller.—The controller cover should occasionally be removed and the different contacts and fingers examined, and all connections examined to be sure that they are tight. The fingers should give a firm pressure against the drum contacts and should set squarely on the contacts. Adjusting screws should be set so that when the drum is in the off position the fingers will drop below the surface of drum about one-sixteenth of an inch. The contacts should be kept tight on the drum and bright and clean. If at any time there is a tendency to cut and become rough, they should be smoothed up and a small amount of vaseline applied.

Steering Rod Connections.—The ball-and-socket joints at each end of the steering rod are fitted with laminated shims between the socket and cap. As the ball and socket become worn the cap should be removed and sufficient lamination taken off with a jack-knife to take up the lost motion and yet have the ball free to turn in the socket when the cap is tightened up again.

Lubrication of Internal Gear Drive.—The gear cases are packed with a heavy grease which under normal conditions should be sufficient for one year's service. At least once a year the cases should be cleaned and fresh grease added.

Lubrication of Concentric Drive.—The gear cases are filled with oil from the pipe connection at the rear and the oil in the cases should be kept level with the top of this connection. Atlantic Refining Company's No. 6 engine oil or equivalent should be used in the gear cases. Care should be taken that the vent plug at the top of the case does not become plugged up, for if there is no escape for the air in the case when it becomes heated it will force the oil into the motor.

Instructions for Both Models.—The motor bearings are packed with a light grease which should be sufficient for a year's service. At least once a year these should be thoroughly cleaned and new grease added.

The axle bearings are packed with a slightly heavier grade of grease. The wheels should be removed every six months and the bearings inspected and fresh grease added.

The steering gear should have a fresh amount of grease added every four to six months. At all other points where lubrication is required compression grease cups are provided. These cups should be given a turn every day.

Adjustment of Axle Bearings.—In replacing a wheel be sure that the axle bearings are in proper adjustment. The wheel should be free on the bearings but not loose enough to allow more than a slight amount of end play. If necessary, thin washers should be added to get the proper adjustment of the bearings. These washers should be added back of the outer bearings so that the bearing will be in the proper place when the clamping nut is drawn up tight against the shoulder on the spindle.

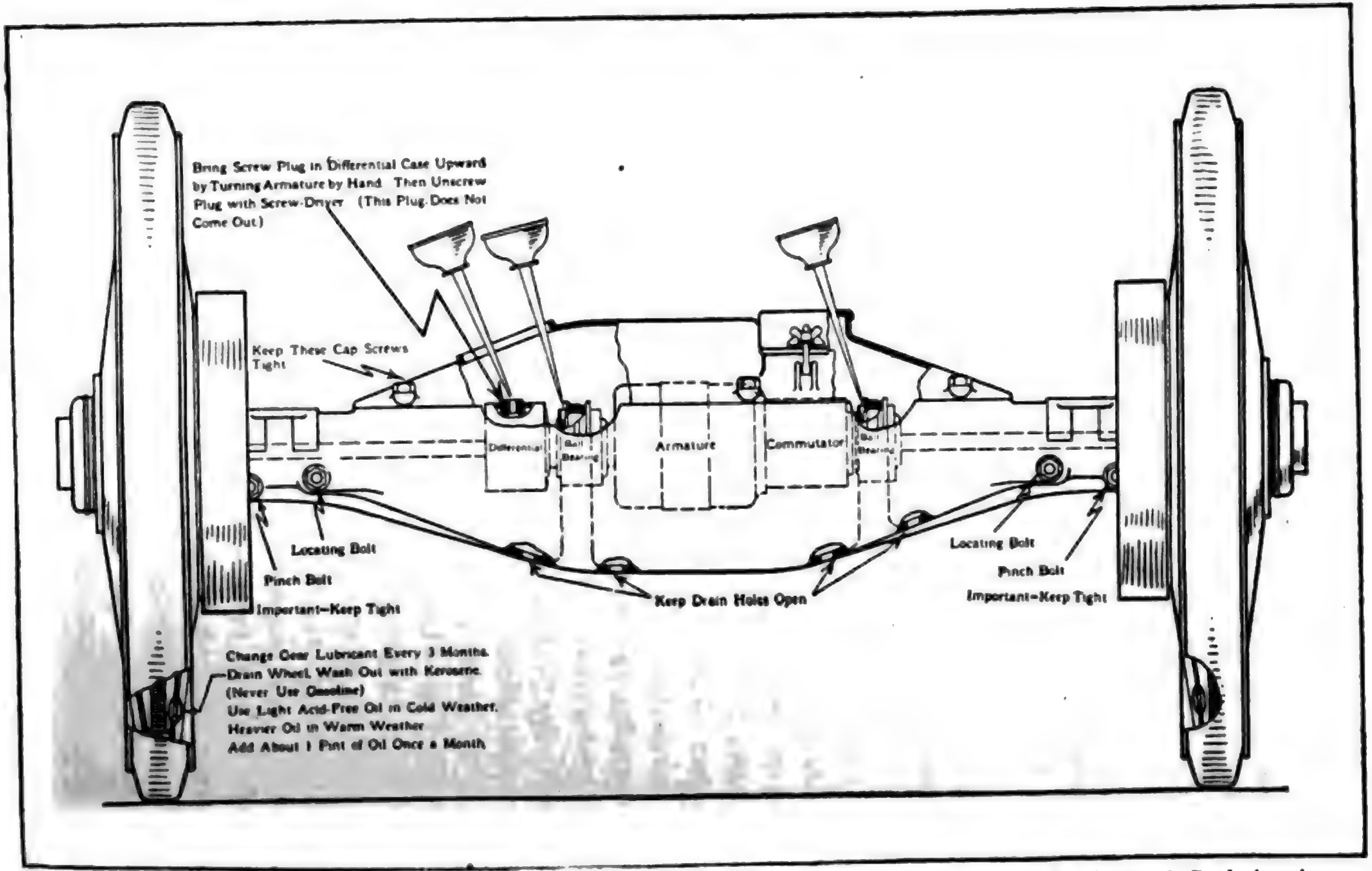

Bring Screw Plug in Differential Case Upward by Turning Armature by Hand Then Unscrew Plug with Screw-Driver (This Plug Does Not Come Out)
Keep These Cap Screws Tight
Differential
Ball Bearing
Armature
Commutator
Ball Bearing
Locating Bolt
Pinch Bolt
Important—Keep Tight
Keep Drain Holes Open
Locating Bolt
Pinch Bolt
Important—Keep Tight
Change Gear Lubricant Every 3 Months.
Drain Wheel, Wash Out with Kerosene.
(Never Use Gasoline)
Use Light Acid-Free Oil in Cold Weather.
Heavier Oil in Warm Weather
Add About 1 Pint of Oil Once a Month

Fig. 520.—Points on Walker Balanced Drive Electric Truck Axle Needing Periodical Lubrication.

INSTRUCTIONS FOR WALKER TRUCK DRIVERS

Starting.—Always allow the truck to accelerate before advancing controller from speed to speed to save undue wear and tear. Do not attempt to force truck ahead faster than wheels will take hold. Make sure that controller is in the "off" position before you insert running key or throw switch to the "running" position.

Stopping.—Stop gradually, as a sudden violent application of brakes produces excessive wear on the tires and undue strain upon the chassis. On leaving the truck when stopping, always be sure to throw running switch to "off" position and remove switch key. SAFETY ALWAYS.

Controller.—Never allow controller to rest between speeds, but move handle swiftly from speed to speed. Never run continuously on first speed, as it includes a resistance which would become overheated; the first notch is a starting speed only. In changing to lower speeds while running, always pull controller to the "off" position and when truck slows down to the desired speed, move controller quickly to the corresponding lower speed position. If for any reason it is necessary to pull off the controller momentarily, without appreciably slowing down the speed of truck, always reapply the power by moving controller to the previous speed position.

NEVER REVERSE THE CONTROLLER WHILE THE TRUCK IS MOVING

Anti-skid Devices.—These are intended for soft mud or snow and if used should be removed when the wheels cut through to hard road surfaces. Do not under any circumstances grind these devices between rubber tires and hard road surfaces.

Traction.—When snow falls, or roads are icy, see that your truck is equipped with one shovel, one box of sand or cinders. If the rear wheels do not take hold use your shovel and sand or cinders.

Speed.—Do not run fast around corners when the streets are slippery. Do not drive downhill any faster than you can drive up. This is very important. Always remember the ability to start or stop depends upon condition of the traction between the tires and the road.

Tools and Supplies.—Do not allow tools, wire, bolts, waste, etc., to accumulate anywhere except in the tool-box. Never lay any metal on battery or in controller box.

Morning.—Be sure battery is fully charged, see that the charging plug is removed, battery doors fastened, and test the brakes before leaving the garage.

Night.—Always leave controller handle in "off" position, remove the running key and set the brakes before leaving the truck.

Daily Report.—Before leaving at night turn in a short report of anything needing attention.

INSTRUCTIONS FOR WALKER TRUCK GARAGE FOREMEN

Washing.—Keep water from reaching the battery. Do not use water with enough force to harm the paint. Avoid the use of soap as much as possible.

Charging (Important).—While charging be sure to have the battery compartment open. Never inspect battery at any time with naked flame. Before inserting the charging plug be sure to have the controller and the running switch in the "off" position, and the lamps turned off. Then throw running switch into the charging position and proceed with the charging.

Driver's Truck Report.—Look this over and if anything needs attention have it done before the truck goes out again—"A stitch in time saves nine." "Oil and grease prevent wear."

Routine Care.—Carefully inspect and thoroughly lubricate with oil and grease as required. While doing this see that all nuts and bolts are tight and in good condition.

WEEKLY

Brakes.—Inspect and adjust when necessary. Do not allow brakes to drag.

Controller.—Inspect and wipe contact surfaces with clean cloth. If rough, polish with very fine sandpaper (never use emery) and wipe with clean cloth slightly greasy with vaseline, but do not use any more vaseline than is necessary to make contacts bright and smooth. When working on controller be sure that running switch key is removed to prevent short-circuits.

MONTHLY

Motor.—Inspect motor and wipe the commutator clean. Further details will be found under "Care of Motor," page 7. Oil armature bearings and differential.

Front Wheels.—Take off front wheels and repack bearings with non-fluid oil. On replacing, turn up axle nut until too tight for wheel to revolve, then release nut one-sixth of a turn and replace axle-nut retaining pin. This will allow wheel to revolve freely without end play.

Rear Wheels.—Lubrication as per instructions.

YEARLY

Overhauling.—It is economical to keep the vehicle as good as new by starting each year with everything in first-class condition. To insure this give the vehicle a complete overhauling.

INSTRUCTIONS FOR THE CARE OF WALKER CHASSIS

Inspection.—Thorough inspection at regular intervals prevents wear, failure and expense. Once a week is not too often for inspection, and the following points should be covered as enumerated.

KEEP NUTS, BOLTS, SCREWS, AND SPRING CLIPS TIGHT. Wear is continuous throughout the life of any truck, and tightening of nuts, bolts, screws, and spring clips is therefore necessary. On new trucks, while the various parts are working into their permanent relation to each other, this is of greatest importance.

Rear Spring and Brake Pedestal Clamp Bolts.—These are the four bolts on each end of axle housing which hold in place the rear springs and also the pedestal casting upon which the brakes are mounted. If these bolts are permitted to become loose, springs are liable to shift, shearing off the spring center bolt, and also permitting the brakes to shift, thus interfering with their proper action. These bolts, as well as all other bolts of importance, are made of vanadium steel, heat treated. This gives them great strength. Give particular care to these bolts on new chassis.

Motor Housing Pinch Bolts.—On underside of each end of rear axle close to wheels. These bolts clamp and locate the stub axles for the rear wheels and must be kept tight, otherwise damage to stub axle and axle housing will result by allowing the key in stub to become loose and shear off.

Disc Bolts Around the Rear Wheel Rim.—Holding the outside disc to the wheel. It is very important to keep these bolts tight, otherwise wear will take place between this disc and the tire band and the oil inside the wheel will tend to leak out.

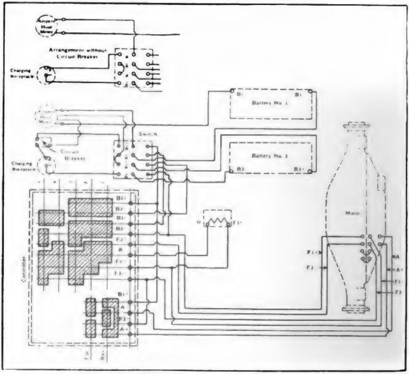

Ampere Hour Meter
Arrangement without Circuit Breaker
Charging Receptacle
Battery No. 1
Battery No. 2
Switch
Circuit Breaker
Charging Receptacle
Controller
Motor
B1
B2
R
F1
F2
A

Fig. 521.—Wiring of Walker Balanced Drive Electric Truck.

Brakes.—Keep brakes in proper adjustment and be sure that they are not dragging. A dragging brake will increase the current consumption materially, reduce the mileage of the truck and make it run slow. The external brake is adjusted by means of the nuts on end of brake band. The internal brake is adjusted by lengthening or shortening the pull rod between the brake evener and brake lever at rear axle. Keep brakes adjusted so that pedals will not strike ends of slots in foot places when brakes are applied.

Alignment of Front Wheels.—Keep front wheels in proper alignment. They should toe in slightly at the front. That is, the distance between the rims at front should be from one-eighth to three-eighths inch less than at rear. If for some reason steering-arms become bent, have them straightened and do not try to align wheels by shortening or lengthening the connecting rod between the steering-arms. Adjusting the connecting cross rod is fundamentally wrong on any car.

Commutator.—Inspect the commutator monthly, but leave it alone as long as it has that smooth, dark, glossy appearance. Most likely nothing will have to be done to the commutator for long periods unless oil or grease is permitted to get on it and cause it to get dirty. If it becomes necessary to clean the commutator, jack up one wheel, block the other wheel and run the motor on first speed only. Hold a piece of fine sandpaper (under no circumstances emery cloth) on commutator as it revolves only long enough to remove the dirt. Do not think that a commutator must be sandpapered occasionally—it should not be touched unless it has become burned on account of arcing of brushes. If merely dirty, clean with cloth moistened with kerosene. If slots between commutator bars are filled with dirt, clean same with thin piece of steel; a broken off, thin hacksaw blade will do this nicely.

Brushes.—See that motor brushes work freely in the brush holders and make sure that springs have not lost their tension.

Armature Bearings.—The armature runs on Hess-Bright ball bearings, and if bearings have to be replaced we recommend this type on account of having race-ways without a filler opening.

Drain Holes.—Four large drain holes in bottom of motor housing must be kept open at all times to prevent accumulation of oil and possible damage to motor. Follow oiling instruction as given under the heading "Lubrication."

Care.—Keep controller free from dirt, rough surfaces and poor contact. These cause arcing, destruction of copper contact plates and fingers and charring of the controller drums. When inspecting do not lift the controller fingers, but tap them lightly. Poor contact will rattle, good contact give a solid sound. Instructions for oiling to prevent wear of plates and fingers are given under "Lubrication."

Proper Handling.—Most damage done to controller fingers and contacts is due to faulty and careless operation on the part of the driver; but these few simple instructions, if followed, will prevent practically all trouble with burnt finger and contact plates. 1. When starting the truck do not move controller handle too quickly into full speed position, but move from one speed to another successively in order to give truck time to accelerate. If moved into full speed position too swiftly, the motor will draw an excessive amount of current which is liable to heat contacts unduly, or even burn them.

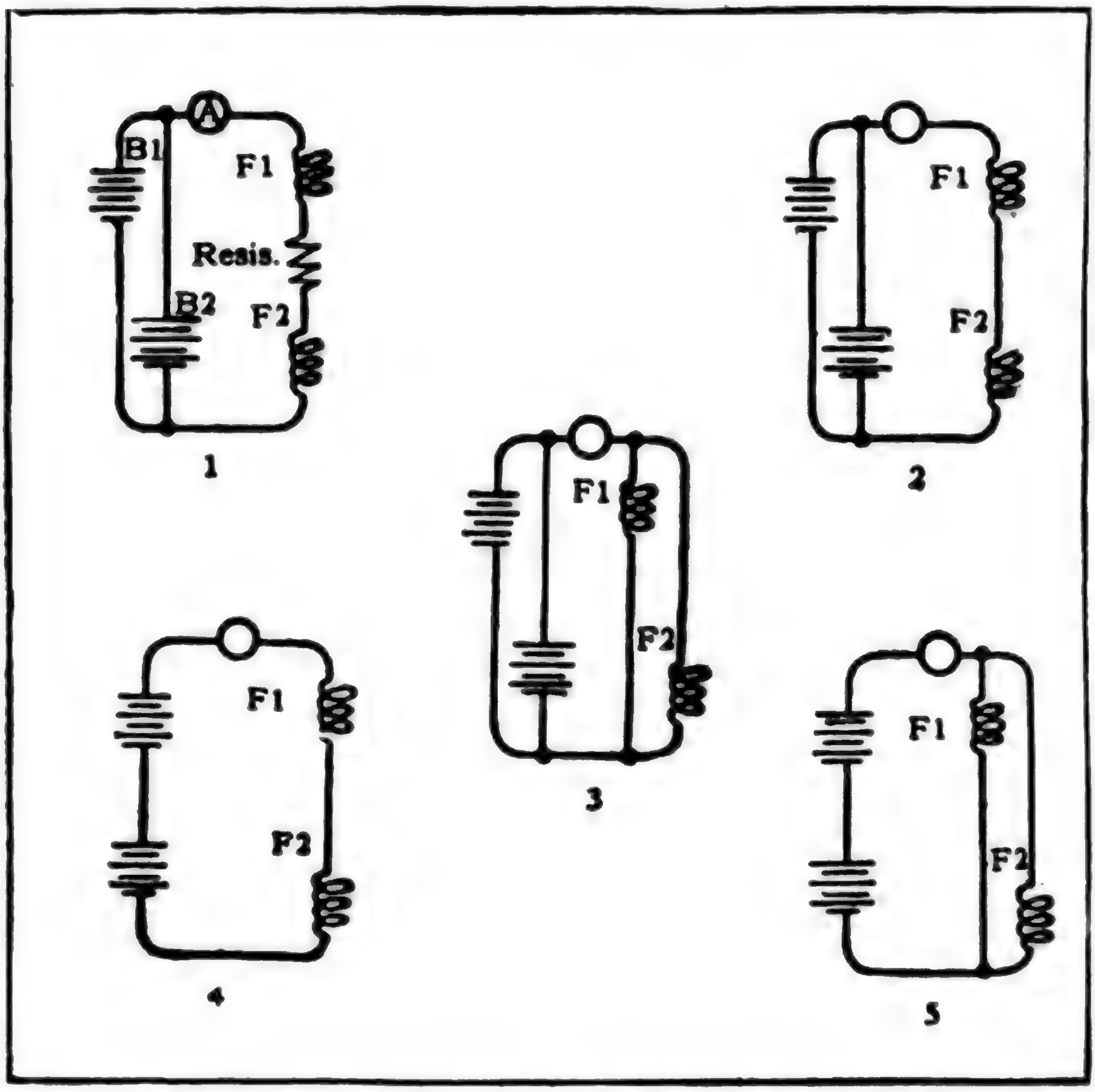


Fig. 522.—Various Speed Combinations of Walker Balanced Drive Electric Truck Controller.

2. Move controller handle to the different speeds with decision and swiftly, and do not linger between speeds.

3. Never pull the controller back a notch or two in order to go into lower speeds. When desired to go into lower speed

pull controller off all the way first and then move it ahead quickly into the speed desired.

4. When driving along at a certain speed if it becomes necessary to pull off the controller momentarily (without slowing down the speed of truck appreciably), when power is applied again the controller should be moved quickly into the previous speed position.

5. Be sure that controller handle is pulled back all the way when stopping, and when leaving the truck be sure to throw off the running switch and remove switch key. SAFETY ALWAYS.

6. Never insert switch key or close running switch until you are sure controller hand is in "off" position. When placing truck on charge put in charging plug before you throw the running switch into charging position, otherwise plug or receptacles are liable to be burnt.

7. Never reverse the controller while truck is moving forward.

STORAGE BATTERY

The storage battery company's printed instructions should be followed to the letter.

AMPERE-HOUR METER

The Sangamo Ampere-Hour Meter is designed to indicate the state of the charge of the battery at any time. When the charge is completed the hand on the dial should be at zero. When the truck is on the road, the hand on the dial indicates the ampere-hours taken out of the battery. If the driver knows the ampere-hour capacity of the battery and the average ampere-hours he has left in the battery, he can, therefore, judge the distance he can travel before the battery is exhausted. All batteries require a certain percentage of overcharge in order to keep them in good condition and to allow for losses in the battery itself. All Sangamo ampere-hour meters on Walker trucks are provided with an adjustment which can be set so that the hand on the face of the dial travels at a slower rate while the battery is charged than when it discharges. This adjustment is located on the underside of the meter and is set at the factor to run 20 per cent slow for Edison batteries and 10 per cent slow for lead batteries.

Any other percentage can easily be obtained by setting the small hand on this dial on underside of meter to the required percentage. Back cover on meter has to be removed in order to get at this dial. See printed instructions issued by the Sangamo Electric Co., Springfield, Ill.

Current Consumption.—By dividing the ampere-hours used by the number of miles run, the ampere-hours per mile will be obtained. It is important to study this particular item, as it not only indicates whether the vehicle is operating properly, but also whether the driver is handling the vehicle in the proper manner.

If there is anything wrong with the vehicle, such as dragging brake or anything which might cause the car to run slow and consume a large amount of electricity, it will be indicated by relatively high figure for ampere-hours per mile; or if the driver is careless in driving his vehicle—that is, starts too rapidly and fails to coast to stops, but turns almost to stops before pulling his controller off and then applies the brakes hard—the figure for ampere-hours per mile will be relatively high.

It should be the aim of the driver to report as low a figure in ampere-hours per miles as possible. Many drivers when they first start to drive an electric vehicle will consume much more electricity than after they have driven it for a time. A good driver is one who has learned to drive his vehicle properly and is a very valuable asset to his employer.

Interchanging Rear Wheels to Reverse Gearing.—It is advisable to change rear wheels from one side to the other possibly once a year, as in so doing the opposite side of the gear teeth are used, thereby doubling the wearing surface ordinarily obtained in other trucks. Pinions should be changed so as to be kept with same wheel. This will materially increase the life of the gearings.

TO REMOVE A REAR WHEEL

First.—Jack up the rear axle until wheel clears the ground. Use a substantial jack and also put safety blocking under the axle to avoid danger from jack failure. Put jack under axle and not under brake pedestal or other parts of brake rigging.

Second.—Take off the hub cap and remove the drive shaft, retaining spring with tongs furnished by us; then pull out the driving pinion and shaft.

Third.—Loosen the "pinch bolt" (located on the underside of the rear axle about one inch from the wheel); then remove the lock bolt located about four inches from the pinch bolts.

Fourth.—Drive the thin steel spreader wedge (furnished by us) into the slot between the pinch-bolt lugs. The stub axle will thus be freed and the wheel with stub axle can be pulled off. (Caution: Do not drive the wedge in far enough to hit the stub axle.)

Fifth.—See that the key located in the upper side of the stub axle is always in good condition before replacing the wheel.

WALKER TRUCK LUBRICATION

Lubrication prevents wear. It is the proverbial stitch in time. A chart showing lubrication of Walker Balance Drive Unit will be found at Fig. 520.

Armature Bearings.—Apply non-acid medium light oil once a month. Only a small quantity required.

Differential.—Remove the hand-hole cover in the top of the rear axle motor housing; then bring the screw plug in differential case upward by turning armature by hand; then unscrew plug with screwdriver (this plug does not come out); then fill differential with non-acid medium light oil and be sure to screw the plug down solid to prevent throwing oil out. Oil enters differential slowly through small holes in plug.

Driving Gears in the Rear Wheels.—Use a heavy non-acid oil in warm weather and lighter oil in the cold weather. There is a screw plug located in each inside disc of each rear wheel near the rim. If plug is removed when it is nearest the ground, oil will run out and will practically drain the wheel. If no oil runs out, the gears are not getting sufficient lubrication. As a rule add only half a pint of oil once a month. Do not fill up wheel —a quart or two is ample.

Brake Toggle Pins for External Brake.—A little oil should be squirted on these from an oil can occasionally to prevent them from seizing.

Grease Cups.—Keep supplied with a light grease and give one turn daily. It is not sufficient to fill and screw down. Make sure that the grease reaches the bearing. Grease cups are provided for the following parts: Brake Cams, Toggles and Pedal Fulcrums, Spring Bolts, Steering Pins, Steering Knuckles.

Controller.—The controller contact plates should be wiped with a cloth only slightly wet in vaseline or good acid-free oil at each weekly inspection. This removes dirt and prevents excessive wear and consequent loose contact between fingers and contact plates. Leave no lint or excess oil to collect dirt. Oil holes will be found at the principal bearings. Wiring diagram of Walker electric truck is shown at Fig. 521 and various speed combinations at Fig. 522.

Winter Operation in the Garage.—There are two main reasons for housing electrics in a reasonably heated garage.

1st—Storage batteries give less capacity if allowed to attain very low temperatures.

2nd—Care and inspection are both likely to be neglected where quarters are uncomfortably cold for the workmen.

Where it is impossible to have artificial heat, care should be taken to keep out extreme cold. After charging close up battery compartment to conserve the heat which the batteries have generated while charging. A very good plan is to charge late during the night, so that the finish will come just before the vehicle is taken out in the morning.

Winter Operation on the Road.—Have the battery box closed so as to exclude cold air. This will prevent the batteries from chilling while the truck is upon the road.

CHAPTER XVI

TRUCK OPERATING COST DETERMINATION

Changing from Horse to Motor Delivery—Horse Inefficient as a Machine—Motor Truck Advantages—Technical Assistance Valuable—Comparing Horse and Truck—Formula for Motor Truck Efficiency—Size of Business—Long Hauls—Short Hauls—Combination of Long and Short Hauls—Road Conditions—Idle Time—Route Planning Important—Variable Loads—One-Way Loads—Increase of Business—Long Distance Motor Transportation—Motor Truck Freight and Operating Costs—Need of Systematic Maintenance and Cost Records—Determining Motor Truck Costs—Typical Cost Data—The Ton-Mile Basis for Cost Figures—Relation of Miles and Ton Miles—Full Load Basis—Half Load Basis—Fractional Load Basis—Bonus Systems—Fixing Standards—One Method—The Three Factors in Bonus Systems—Poor Economy in Towing Horse Wagons—Obstacles to Manufacturer's Inspection—Manufacturer's and Dealer's Service—System is Very Thorough—Reports Made in Triplicate—Neglect of Truck is Shown—Inspectors Ride on Trucks—Vim Service Station System—Cashier Must Release Machine—History Card Shows Condition— Value of Requisition Forms—Instruction for Parts Disposal—Typical Requisition Forms—Truck and Trailer Laws Digest.

Changing From Horse to Motor Delivery.—"Shall we install trucks, or shall we continue with our horse delivery system?" This question is perplexing thousands of business managers today who are confronted with a delivery problem, and who realize that it is not only desirable but necessary to decide the question correctly. It is our aim in this chapter to analyze the fundamental questions involved in this problem in such a manner that these merchants may apply certain basic principles to their own situations and arrive at a decision upon which they can depend. The matter was discussed in an interesting way in the book, "Motor Trucks of America," published by the B. F. Goodrich Company, of Akron, Ohio.

It is only fair at the outset to admit the impossibility of setting down any hard and fast rule which covers all the possible cases that might come up for consideration. Every one is a law unto himself, and every one requires individual scrutiny and analysis. Often two dissimilar delivery problems are equally adaptable to the economical use of motor trucks. There are a dozen or more features to each problem which must be considered and every one must be given its due weight. It will not do to say "This man has long hauls, therefore he needs trucks;" or "this man carries heavy loads, therefore he needs trucks." It may be that the long hauls are made upon crowded streets where the speedy truck has to crawl along behind slow-moving dray wagons, or the heavy loads may be hauled no farther than around the corner.

Horse Inefficient as a Machine.—What makes the problem pressing is the knowledge that the horse is, considered by his own performances, a wasteful machine. As a motor he is but two per cent efficient, so far as heat units are concerned. That is, of the heat energy taken in with his enormous meals, he transmits but two per cent in draw-bar pull on the vehicle behind him. His limited hours of labor, and his comparatively small capacity for load and speed, considered in connection with the expense of feeding, caring for and housing him (as well as his bulky vehicle and harness), condemn him at the start for inefficiency in transportation.

Motor Truck Advantages.—On the other hand, the principal advantages of motor transportation are conspicuous. The mere economy in garaging these compact engines, requiring, as they do, about one-eighth the space of the horses and teams they replace, is a notable item. Instead of being two per cent efficient, they transmit from fifty per cent to seventy-five per cent of the energy of their "meals" into action. Moreover, their great speed and their tremendous capacity for load make them veritable giants in transportation.

The mere fact, however, that the motor truck is potentially fifteen to twenty times more efficient than the horse does not clear up the perplexity of the progressive business manager who is studying his delivery problem. The greater question still remains to be answered: "Are the conditions of my business such that I can take advantage of this superior efficiency of the motor truck?" Here he is asking a question which cannot be answered categorically. It can only be answered by a careful examination of the several phases and conditions under which the transportation end of his business is operated.

Technical Assistance Valuable.—At this point, the average business man needs the technical assistance gained by experience. The capable truck salesman, acknowledging this fact, spends as much time in going over the special requirements of his prospect's business as he devotes to the description of the superior qualities of his truck. Fundamental facts are investigated, as they are more important than the particular features of a truck. Such an examination is made not without difficulty. It is possible, however, to lay down a principle and apply it, using it as a guide rather than a hard-and-fast rule. This guide is the principle of motor-truck efficiency.

The reason for the existence of the motor truck is that it carries more and goes faster than a horse and wagon. This is its fundamental justification. A truck constantly working with a capacity load attains the maximum of efficiency. According as it is interrupted in its daily travel and according as its load falls below its rated capacity, by so much does it fail to realize the hundred per cent efficiency of which it is theoretically capable.

Comparing Horse and Truck.—Let us compare, for instance, a single horse and wagon capable of carrying half a ton at a speed of four miles per hour, with a two-ton truck, which is able to carry two tons at a speed of twelve miles per hour. Using the speed and load of the horse-drawn vehicle as units of comparison, we find that the truck develops three units of speed and carries four units of load. Carrying out these figures, we find that the two-ton truck performs twelve units of work as compared to a single unit performed by the horse and wagon. This comparison will be clearer if we consider that the truck carries four times the load but develops only the same speed as the horse and wagon. Now if this speed is increased to three times that of the horse, it will be seen that the truck not only carries four times but carries it three times as fast as the horse-drawn vehicle, making the relative working efficiency of the truck twelve times that of the horse.

Let us now suppose that this truck which is capable of thrice the speed and four times the capacity of a single team, carries its load on a certain trip at a rate of eight miles an hour. Inasmuch as it develops twice the speed of a team and carries four times the load, it still performs eight times as much work as the team.

Imagine that this truck runs half a ton in the afternoon. Its average load for the day is one ton, which is twice the capacity of the team, and with a speed of three times and a load of twice the team capacity, it does the work of six teams, even though during half the day it was engaged in carrying a load far beneath its capacity.

Formula for Motor-Truck Efficiency.—With these facts in mind, we are able to produce what may be termed a formula of motor-truck efficiency, using the efficiency of a single horse and wagon as a standard. This formula may be expressed as follows:

SPEED	X	LOAD	=	WORK
As Compared With Team		As Compared With Team		As Compared With Team

Or, leaving off the explanations, which are now understood, we may say that SPEED X LOAD = WORK.

This definite formula, while not conclusive, we believe will prove decidedly valuable as a guide to the business manager in analyzing his delivery problem, lest he go astray in the intricacies of a confusing analysis. Transportation engineering is not an exact science, although it is far better understood now than ever before. Many variations will develop in different lines of business, as a result of which the formula above may not accurately disclose the result sought.

In applying this principle to any delivery problem, the investigator should remember that it is seldom a truck develops anywhere near one hundred per cent transportation efficiency. Considering that such a truck would travel four times as fast and carry four times the load of a single horse and wagon, we arrive at the astonishing fact that this single truck would replace sixteen single teams. If a power wagon system could be operated on such a basis, there would be no problem involved. It would pay at once to substitute it for the horse-drawn system. One should not, however, refuse to consider the possibilities of a motor-delivery system merely because, early in the examination, it is discovered that the trucks must carry less than their capacity load and stand motionless much of the time. The problem requires careful accounting to discover what conditions have a bearing on the basic formula.

The following are the most important external factors which affect the speed or load of trucks, and consequently affect the work or returns to be expected from them:

(1) SIZE OF BUSINESS. Obviously, the size of a given business determines whether there is a transportation problem big enough to involve the use of even one truck. As a general rule a merchant having more than two single-horse wagons should begin to give consideration to the question of motorizing his delivery. It is generally said that one truck will replace four such wagons. No one can say definitely how many teams can be replaced by one truck, except in a given instance. There are certain kinds of business, notably freight and transportation lines, in which one truck has replaced sixteen single-horse wagons. The size of the business, however, gives one merely a preliminary idea as to the advisability of motorizing. A further analysis of the conditions of delivery is necessary before a reliable conclusion can be drawn.

(2) LONG HAULS. The condition, par excellence, in favor of motor truck operation is one involving long hauls. In fact, it may be almost said that any one having to make long hauls in his business should motorize at once without further debate, as the case for trucks is practically settled by the mere statement of this condition. In making long hauls the truck has the chance to show that speed which is half the secret of its efficiency. Even if the other half—the capacity for load—were entirely missing and it carried merely the cargo of a single-horse wagon, it would still do the work of four or five horses, because it would operate from four to five times as fast. Commonly, however, it has a good load to carry as well, in which case both factors of our formula, speed and load, are present, making the resultant product, "work," very high. On long hauls a single truck has often replaced a dozen or more horses and wagons.

(3) SHORT HAULS. Transportation involving short hauls is the obverse of the deal, and as a general thing represents a condition unfavorable for the operation of motor trucks. The factor of speed is, of course, the most noticeably affected. In going short distances the truck has scarcely time to get up to high speed when it has to stop. Of more serious consequence than that, however, are the stops made to deliver goods. Frequent inaction, of course, reduces the average daily speed just

as effectively as slow driving. If a truck were going at full speed half the time and were inactive the other half, its daily speed would be computed as one-half its potential speed. Moreover, the factor of load is affected by short hauls. For example, if it takes a whole morning to deliver a load piecemeal, while no load is carried in the afternoon, then the average load carried is only one-half what the truck might haul.

The experience of many concerns is worth noting, however, that deliveries made to several points which are over three blocks apart are just outside the classification of short hauls, and at these distances, limited though they may seem, a fast truck can often perform to such advantage that its substitution for horse and wagon will prove advisable.

(4) COMBINATION OF LONG AND SHORT HAULS. It sometimes happens that although business requires long hauls to certain districts, it becomes necessary to make many short hauls and stops in the course of actually delivering the merchandise. In such cases, it is necessary to figure carefully to prevent the error of buying and using trucks wastefully. Obviously, while the truck is spinning along at its maximum speed and with a capacity load toward the region in which the distribution of goods must take place, it is developing its full working efficiency. Once arrived there, however, and employed in making house-to-house deliveries, it becomes scarcely more efficient than a single horse and wagon. Its speed, which is its chief asset, is cut down to almost nothing. And more than that, its load suffers a gradual reduction over a long period of time, so that in many instances a truck engaged in deliveries of this nature may work a whole day with an average load of but half its capacity.

Many traffic managers, when confronted by a situation of this kind, employ one or two trucks to make trips at high speed along the radii which lead to the outlying districts where actual deliveries must be made. Once loaded, these trucks without stopping, deliver their entire burden to suitable stations from which, after redistribution into small units, it is taken up again by horse-drawn vehicles, more suited to the work of house-to-house delivery. Department stores which make deliveries to distant suburbs sometimes find it profitable to use small, fast delivery cars exclusively. These machines, to begin with, cost no more than a good horse and wagon equipment such as they would otherwise have to maintain. There would be no economy, therefore, in transferring a load from one conveyance to another of similar capacity, while such a method might involve a decided loss, due to the slower pace of the horse, delivery, and to the longer hours of the driver and helper.

(5) ROAD CONDITIONS. Bad road conditions may sometimes affect the efficiency of motor trucks by cutting down their speed, or by making necessary frequent overhauling and adjustment of their mechanical parts. There are very few cities in this country in which the imperfect road conditions are a serious obstacle to the introduction of motor trucks, provided other business conditions would justify their use. In fact, in typical American fashion, certain cities whose normal growth and development have been hindered by the burden of old and worn-out pavements which have prevented the use of both motor cars and trucks, have recently appropriated large sums of money for repaving with a view to overcoming these handicaps. Such difficulties are too often magnified out of their true proportion, however, and many a merchant allows himself to be frightened away from an aid which might save him hundreds of dollars in his annual transportation bill.

Again steep grades may make it necessary to haul loads of less than the normal rated capacity of a truck. This apparent disadvantage may be overcome by other conditions which in comparison with horse-drawn service, stamp the truck as much more efficient than the team. For example: In the sultry, withering heat of summer the truck when traveling up grades doesn't require the frequent rests, and consequent loss of time, necessary to prevent prostration, while the last two winters have abundantly proved the dependability of the motor in conditions of snow and ice which render the horse highly uncertain and far less powerful even when sharp shod.

(6) IDLE TIME. It sometimes happens that the pressure of business varies greatly during the course of every day, so that while a truck may make a long and profitable trip at one time of the day, it may stand idle a large part of the time. This is, of course, not a favorable condition for truck operation, although it cannot be adjudged so in any particular case without careful accounting. Idleness or its equivalent, slow motion, may also be produced by the congestion and delays often met with at

freight terminals and docks, or on crowded streets, to say nothing of the greater delays often occasioned by the condition of the merchant's own shipping and receiving departments.

While all these factors should be recognized and introduced in our formula at their real value, the merchant should early realize that the advent of the motor truck means a new order of things with regard to shipping facilities and shipping programs. The horse has long been with us, and the impress of his personality and slow ways still remains on our commerce. His lagging pace, his limited capacity for load, his limited hours of labor, and most important of all, his low cost and that of the vehicle he draws—all these things have been faithfully reflected in our shipping rooms, our shipping clerks, our freight docks, and our terminals.

The motor truck is comparatively expensive. It commonly replaces three or four wagons, and when it is standing still, four horses are lying idle. It is capable of good speed and enormous loads. It asks for work; and when given its capacity it starts complacently away with a cargo which five horses could hardly stir, and carries it four times as fast. By doing these prodigies it can stand idle at our horse-planned shipping rooms and freight docks, and still, out of the bounty of efficient performance when in action, declare the merchant a profit. Idleness, however, is a spendthrift waste, and one which should be eliminated.

The merchant, therefore, has to approach this question of idle time from two points of view. While he must faithfully recognize those factors in his business which may prevent his giving steady employment to one or more trucks, he must also look sharply into every department of his business to see whether it cannot be re-arranged or "speeded up" so as to enable him to take advantage of this valuable machine in transportation.

Route Planning Important.—Proper planning of deliveries may make it possible to keep one truck busy all day, eliminating as many as five horses. Problems which require more flexible treatment may often be solved by a combination of truck and horse-system, as was suggested in the case of the merchant who had to transport his goods several miles from his store and then deliver them practically from house to house. The average merchant may be surprised to discover, upon examination, that his present delivery system is capable of alteration. And it is the exceptional business using at present three or more horses, which cannot, by careful and creative planning be made to accommodate a motor-delivery system with better results. The merchant who does not conscientiously examine his own business with that idea in view is cheating himself of an opportunity which his keener competitor may be using against him.

Besides replanning deliveries, it is generally necessary to revamp the shipping-room. The average shipping department is dominated by the very spirit and presence of Old Dobbin. Here easy customs prevail. The average traffic manager suffers no special pang to look out upon his horse and wagon standing idle perhaps an hour before being loaded and another half hour while being loaded. Now, progress has changed all this. In the larger centers, where motor delivery is practically universal, we see traveling belts, gravity chutes, and spiral slides, escalators for carrying heavy articles, and various other devices for feeding the cargo on to the waiting truck in a fractional part of the time in which the grocer loads his wagon. In many cases, elaborate apparatus cannot be installed, but the business manager may as well absorb the spirit of such devices and infuse it into his shipping department, so systematizing and speeding it up that the load shall be waiting for the truck, not the truck for the load.

•(7) VARIABLE LOADS. Just as idle time affects the factor of Speed, in our formula, so conditions involving a wide variation in the amount to be carried affect the factor of load. Consequently, if the load factor falls below what might be called an average load for four horses, the resultant product of work will doubtless be so small as to render the use of a motor truck unprofitable. If, however, the truck is constantly busy with an average single-horse load, it may still operate more advantageously than horse delivery, because the truck is able to do the work of four or five horses by means of its four- or five-fold greater speed. If, therefore, a given transportation problem involves the moving of widely variable loads, the most satisfactory solution is to be found through the use of trucks whose capacity is somewhat under that of the average load to be carried. Rather than employ units which can, in one load, carry away bodily the accumulation of a day's freight, it is considered better practice to have two or three smaller trucks which can keep busily pegging away, moving part of the merchandise, at the same time leaving a certain amount behind like a balance in the bank. If the factors of load and speed are thus kept up to a fair average, the resultant amount of work produced is considerably greater than would be economically possible by means of horses.

This principle, though, if followed blindly, will lead on into difficulties. If a man wishes to move four tons of reasonably compact merchandise, it is, generally speaking, cheaper to use a single four-ton truck than two two-ton trucks. Where a load of definite size and weight can be depended on, the most satisfactory course is to buy a truck to fit that load. It would not be in the least economical to employ several trucks every day moving merchandise that one truck of the proper capacity could carry.

Merchants who have a large business but still have the problem of variable loads to contend against, sometimes use one large truck and several small ones. In this way, the large truck may be kept busy moving capacity loads, in the most economical fashion, while the smaller trucks, when not engaged, are not so expensively idle.

(8) ONE-WAY LOADS. Although a business house having one-way loads to contend against has an expensive transportation problem to begin with, the use of motor trucks should be seriously considered, especially if long hauls are involved, in which the trucks may develop fairly high speed. Many truck lines do a one-way business and show a profit over horse and wagon, solely because of the speed factor.

(9) INCREASE OF BUSINESS. There is another consideration, however, which is altogether separate from the matter of truck efficiency, but which may prove to be more important than all the factors which we have considered. This is the possible increase of business afforded by the comparatively greater field of operations of the motor.

It can be readily seen that if this increase of business amounts to much, the additional profits may take care of the entire expense of the transportation, making it a sort of free gift to the business. We are inclined to believe this phase of the question deserves more and receives less consideration from the business man than almost any other. This is perhaps because it requires creative imagination. The merchant, however, who knows how to reckon on this future gain is doing creative planning of the highest order, and may expect rewards in proportion.

We have now indicated the most important conditions of business operation which affect the speed and the loading of motor vehicles and consequently their work. The manager who will apply these principles to his own business can tell with reasonable certainty what motor trucks will do for him. His problem from now on is one of accounting.

The formula Speed X Load = Work has served its purpose, for it has told the merchant what part of the possible hundred per cent efficiency of motor trucks the conditions of his business permits him to obtain. With a view to answering the question asked at the beginning of this discussion, he must now figure out in dollars and cents whether the Work of Trucks compared with their Cost exceeds Work of his Horse Delivery compared with its Cost. It is apparent that whatever we may say against that discredited animal, the horse, we must take off our hats to him in this one respect; he is still the standard by which other means of city and suburban transportation are judged, according to cost and according to results. The question then is how does the cost of motor delivery compare with that of the horse standard?

We can do no more in this paper than indicate the points which will come up in such a comparison. The cost of his present equipment is no doubt all too well known to the merchant. The feed bills, the stable rent, the wagon repairs, these appear in concrete form on his ledgers.

The cost of the new equipment is not known, but may be estimated closely. The first cost of the trucks, is, of course, to be had to a cent. This, however, should not be charged against one year's expense, but should be distributed over the several which can confidently be expected as the term of life of a good truck. The old equipment must be disposed of perhaps all at once, perhaps gradually. Certain expenses will be incurred in making over the shipping-room to accommodate this new type of transportation service. As to the cost of operating the trucks, reliable figures may be obtained from truck agents or commercial journals which will give him a pretty close estimate. Certain things are already known to him: such as wages, interest, and terms of payment for the trucks. To these he must add such factors as garaging the trucks and keeping them in repair.

Knowing the cost of his present equipment and the results he is getting from it, and having scientifically estimated the cost of a truck delivery system and the results to be expected from it, he is thus in a position to make a reasonably convincing comparison, the result of which should have a distinct and logical bearing on his decision.

Long Distance Motor Transportation.—The problem of good roads is only one part of a bigger problem—transportation. It is necessary to state this obvious fact for the simple reason that the obvious is usually the last thing we see. The other half of the problem is vehicles, plus their motive power. Good transportation has resolved itself into two things: good roads and motor trucks. A favorable sign of the times is the growing recognition on the part of good roads advocates that good roads exist for the use of better transportation media—the motor truck and the automobile. The motor truck is not only replacing horse transportation, but in many cases it is supplanting railroads. The motor truck is the solution of the modern transportation problem.

In addition to the unlimited use of motor trucks for delivery purposes, they are substituting for railroads, where the railroads themselves are using them to replace spurs, which are a source of expense and difficulty. Also in inter-city shipments large truck companies operate transportation service for merchandise, supplies, etc. An idea of the extent of this form of transportation which is calling for better roads and the best motor trucks is given by the example of Callan Brothers, of New York, who operate a motor truck transportation system within a radius of 400 miles of New York City. They have a fleet of over forty seven-and-one-half-ton trucks. They have closely connected their service with the Erie Barge Canal, which runs from Buffalo on Lake Erie across the State of New York, joining the Hudson River at Troy, a distance of 387 miles. Callan Brothers have linked their eight large warehouses, with a storage capacity of 900,000 square feet, and their motor truck service with the terminals of the canal in New York City and important up-state transshipment points along the canal. The Harlem River Ship Canal is eight miles long. Callan Brothers unload freight direct from the canal barges at their warehouses alongside their yard for shipment by their large fleet of motor trucks and deliver direct to consignees or to warehouses to be held for future delivery in New England, New Jersey, Delaware, Pennsylvania, or other seaboard states or to trans-Atlantic piers in New York City.

These motor-truck transport systems are claimed to be the outcome of the inability of the railroads to handle the great quantities of freight which have congested railway traffic in all parts of the country. This condition is responsible for the discovery of the real value of the motor truck as a transportation medium. Motor trucks were used in connecting the broken lines of railroad shipping and are replacing the use of local freight trains on "short hauls" to a considerable extent, thereby releasing freight cars for the more essential shipments on longer hauls.

Shipping freight by motor trucks means less handling, less damage and safer delivery. It eliminates at least five handlings of goods as shipped by railroad: first, from factory or warehouse to freight station; second, loading from freight station or truck to cars; third, unloading at destination from cars to trucks or freight station; fourth, unloading from trucks to stores, factories or warehouses; and fifth, handling in case the goods are removed from the car to freight station and held until the consignee sends a motor truck to remove them.

Distances considered practical for motor-truck transportation are held by various authorities to average from 100 to 300 miles. In special instances, trips of 400 miles have been made. The establishing of long-distance motor-truck service during the emergency of the war is undoubtedly the forerunner of a continuation of such service on an even larger scale in the era of peace. The service is demonstrating to manufacturers and merchants that motor-truck transportation is the only way to escape delays caused by the slow-moving local railroad freight trains and the loss of time that had frequently been experienced even before the railroad freight congestion became so acute.

When counterbalanced by their capacity and more extended distance of travel, the upkeep of motor trucks has proved to be less expensive than the maintenance of horses. One of the big Mack trucks of the Callan fleet has been in the service for four years, and it has never had its engine taken down for a general overhauling. It is still in commission, carrying its rated capacity load every day. The following is a schedule of the distances and time made by Callan Brothers' seven-and-a-half-ton Mack trucks:

The schedule gives a practical insight into the transportation methods of the immediate future. Motor truck transportation has come to stay. The problem now is to perfect and develop it.

	Miles	Hours per Trip
New York to Philadelphia	100	12
New York to Baltimore	188	22
New York to Dover, Del.	172	21
New York to Waterbury, Conn.	95	11
New York to New Haven, Conn.	77	9
New York to Bridgeport, Conn.	58	8
New York to Hartford, Conn.	113	16
New York to Springfield, Mass.	139	18
New York to Worcester, Mass.	190	23

Department stores in New York City and Philadelphia are extensively patronizing long-distance motor-truck freight service. This method of transportation insures prompt receipt of goods.

The products carried by motor trucks have hardly any limitations. Recently several tons of finished leather, valued at $40,000, were shipped by motor truck from Philadelphia to New York over night. Railroad service at the same time would have required from four to seven days. Machinery manufacturers and cotton and woolen mills in New England cannot well afford to await the arrival of slow incoming freights, so they have their raw materials delivered to them by motor trucks in express time. Heavy machinery is delivered direct from shops and foundries in Connecticut to factories in New York City. Wholesale grocers deliver in Washington from warehouses in Baltimore. Tons of high explosives that railroads refuse to carry are delivered by motor trucks with but one handling after they leave the chemical works. And so on "ad infinitum."

Engineers who for years have been engaged in the building of better roads are now including in their efforts the problem of better motor transportation. They realize that good roads are but a means to an end—efficient transportation, the getting of things from where they are to where they are needed in the best, quickest and most economical manner.

Within a range of 50 to 100 miles the motor truck is today easily a competitor on better than even terms with the railroads. All that is needed to widen the limits of this zone is the building of smooth, hard-surfaced highways of adequate strength. Government recognition has been taken of this fact, and a new government department is to be born out of the stress of the great war. Its purpose will be to create a country-wide system of roads that can be used in winter as well as summer. This has the double strategical value of a strictly military measure and of relieving railroads. It is now proposed that topographical maps be prepared showing our present loosely constructed and unsystematic highways. With these as a basis, a plan will be made of an interlocking system of roads, upon which the products of the nation may be moved from coast to coast, and from the Canadian border to the Gulf of Mexico. New and sounder types of roads than heretofore will have to be constructed, having as the first consideration the greatly increased wear and tear of heavy trucks. Even the best of our existing highways are not calculated to withstand continuous traction of heavy duty trucks.

Farmers are turning to motor-truck transportation. Thousands of them are now served by motor-truck express lines without which they would hardly be able to ship milk or farm produce. This service has enabled them to materially increase their production, with a certainty of reaching the market. In Maryland there are twenty such lines carrying supplies into Baltimore and Washington. They have a daily capacity of 115,690 ton-miles and haul more than 500 tons a day into these markets and take back an equal amount of merchandise to farmers and country merchants. The United States Food Administration states that one man with a truck can haul as much farm produce as three men with wagons, and cover three times the distance. All of this emphasizes in a general way the conditions that have obtained in railroad transportation and explains why industrial and commercial interests are turning more and more from what had been considered "short hauls" to the use of motor trucks for transportation. Business men first turned to motor-truck service to meet an emergency; now they are turning to it to insure against interruptions and delays in carrying on their operations.

Motor Truck Freight and Operating Costs.—In handling freight by motor trucks, says R. E. Fulton, of the International Motor Company, New York, two principles are involved: First, service; second, cost. Every question in connection with the use of motor trucks falls under one or the other of these heads.

Comparing railroad freight charges with motor-truck freight charges, it is necessary to include all the incidental items of expense connected with them.

Sometimes manufacturers figure that a railway freight rate of 50 cents per 100 lbs. is cheaper than a motor truck freight rate of 75 cents per 100 lbs. between the same points. In the freight rate of 50 cents all the expense of making the shipment, starting with the boxing or packing cost, and all other expenses incurred until delivery is made to the receiver in good order, have been overlooked.

The general traffic manager of one of the largest manufacturing concerns in the United States figured out what it cost them to ship freight by railroad and by motor truck between various eastern points. In railway freight cost he included the first-class freight rate, by which their goods would have to be shipped, plus 15 cents per 100 lbs., teaming charges from shipper's warehouse to freight house, plus 15 cents per 100 pounds teaming charge from freight warehouse to receiver's warehouse, plus 24 cents per 100 lbs. increased cost of boxing to cover shipments on account of increased weight caused by increased boxing.

Without including several other items of expense, this gave the following table of comparative freight rates per 100 lbs.:

From	To	Via Freight	Via Motor Truck
Yonkers	New York	$1.04	$0.20
New York	Newark	.91	.15
New York	Passaic	.91	.18
New York	Paterson	.91	.20
New York	Elizabeth	.91	.20
New York	New Brunswick	.91	.40
New York	Trenton	.98	.60
New York	Philadelphia	1.02	.80
New York	Chester, Pa.	1.05	1.00
New York	Wilmington	1.13	1.20
New York	Coatesville	1.15	1.05
New York	Port Chester	1.02	.63
New York	Greenwich, Conn.	1.02	.63
New York	Stamford, Conn.	1.03	.65
New York	Norwalk, Conn.	1.06	.68
New York	Bridgeport	1.10	.70
New York	New Haven	1.13	.73
New York	Derby, Conn.	1.13	.73
New York	Ansonia, Conn.	1.13	.73
New York	Shelton, Conn.	1.13	.73
New York	Naugatuck, Conn.	1.15	.74
New York	Waterbury	1.16	.75
New York	Meriden, Conn.	1.16	.75
New York	Hartford, Conn.	1.21	.90
New York	Springfield, Mass.	1.25	1.00
New York	Holyoke, Mass.	1.25	1.10
New York	Worcester, Mass.	1.31	1.50
New York	Boston, Mass.	1.36	1.50
New York	Providence, R. I.	1.32	1.10

In addition to this, it is necessary in practically every case to prepare material for freight shipment in an entirely different way than when it is shipped by motor truck direct from shipper to receiver. There is a considerable additional expense for crating, or to protect by other means to prevent loss or damage in transit. This extra expense is necessary because of the number of handlings less than carload shipments received at the hands of teamsters and carriers after the material leaves the shipping department. This increased protection and expense can be greatly reduced if shipments are made by motor truck, as the packages only need protection for loading at shipper's warehouse, in transit without transfer, and unloading at receiver's warehouse. Then, in shipping by motor truck, instead of by rail, a great amount of clerical work in the form of extra bookkeeping, billing, etc., is eliminated. Where extra packing is necessary extra room is required for the boxing department. Then if railway freight shipments are delayed there is the additional trouble of tracing them. If the shipment arrives in damaged condition, there is the further difficulty of collecting from the railroad company.

Contrasted to this is the example of Marshall Field & Company, who guarantee to make delivery within 50 miles of their store within 24 hours, so well is their motor transportation system organized. Boxing often carries from ten per cent to twenty per cent of its weight in moisture, unless it is kiln dried prior to boxing. The Otis Elevator Company estimates that by the use of motor trucks it saves more than $100,000 a year in lumber alone.

Delivery time is all in favor of the motor truck, and if manufacturers will take into account all the various costs and charges which are part of true freight transportation costs, they will find that motor trucks can be operated successfully and economically in competition with railways for distances between 10 and 125 miles. In figuring the cost of operating trucks there are many faulty systems in use. These systems overlook many little items which find their way into the expense account and often cause considerable loss to the operator who overlooks them. The following table gives items of cost which must be determined upon the basis of size of truck, miles traveled and tonnage hauled:

- Assumption
  - Working days per year
  - Miles per day
  - Miles per year
  - Miles life of car
- Investment
  - Chassis with standard equipment
  - Body
- Fixed Charges
  - Interest on investment
  - Insurance
  - Fixed depreciation (exclusive of tires)
  - Wages
  - Garage rent
- Operating Charges
  - Maintenance
  - Tires
  - Gasoline
  - Oil and grease
- Total Cost per Annum
- Total Cost per Day
- Total Cost per Ton Mile

Often trucks will do unusual mileage at surprisingly small cost for repairs. We frequently get letters about Mack trucks that have given exceptional service. One of these unusual cases is that of the two-ton Mack operated by M. Mauro, of Plainfield, N. J., which has traveled 45,000 miles with practically no expense for repairs. Another Mack has traveled 30,000 miles and the only repair expense incurred was $65 on account of the driver allowing the motor to freeze up last winter. Such remarkable service as this cannot always be expected; but these instances serve to show the possibilities of a good truck if given reasonable care.

Need of Systematic Maintenance and Cost Records.—In railroad practice an express passenger locomotive is inspected at the end of every 80 miles—a freight locomotive every 150 or 200 miles. As many as five inspectors work on a locomotive at one time. Each is responsible for certain groups or parts.

As showing the relative cost of different kinds of maintenance service and the importance placed on cleaning and inspecting every part both inside and out, the following distribution of labor on passenger engines may be of interest:

Wiping, cleaning, washing and inspection	60%
Clinkering and firing up	12%
Watching, hostling and calling	12%
Supplying, coaling and sanding	10%
Turn table and laborers	6%
Total	100%

Under these conditions passenger locomotives run 127,000 miles without going to the shop for overhauling—freight locomotives 100,000 miles.

On four out of five of the trunk lines west of New York the locomotive repairs are 4.4, 7, 12 and 16.6 cents. The first road has the heaviest grades of the four, the last road runs 30,000,000 locomotive miles. Its repairs cost 12 cents per mile more than the first—it is losing $3,600,000 a year.

Just as the transportation lines have set down "roundhouse" care as of paramount importance, motor truck operators should give the same subject even more attention, for their machines are traveling over all conditions of road surface, multiplying many times the necessity of inspection work, and, as a rule, the vehicles are not operated by as highly trained and skilled hands as are railway locomotives.

Determining Motor Truck Costs.—In writing on the subject of determination of motor-truck operating costs, Mr. Charles Sidney Lyon, an engineer in the New York Packard sales organization, summarizes the matter in a few words, as follows:

"The reader must bear in mind that the actual cost of operating a motor truck depends on many things, among them being:

Ability of the driver and his interest in the truck.
Inspection, maintenance and periodical adjustments.
Periodical lubrication.
General characteristics of business or trade.
Loading and unloading facilities.
Road and traffic conditions.
Miles per day and length of haul.
Tons per trip.
Operating hours per day.
Operating days per annum.

Obviously, it is impossible to prepare a single chart which will represent exact operating costs, even for two companies in the same business in the same city. In many instances salesmen have given operating cost figures without careful consideration of the transportation problem involved, and in many cases it ended up in a discussion which is quite undesirable. One truck owner will claim that $5.00 a day is too much for a driver and another will prove that he must pay $6.00 or more a day. One owner will claim that three cents per mile for maintenance and overhaul is too high and another will say it is too low.

Insurance cost will vary according to the locality and the line of business. Not all motor truck owners will be willing to establish a sinking fund on a mileage basis. Gasoline consumption will vary according to operating conditions. Gasoline does not sell at twenty-seven cents per gallon in every city. Companies operating large fleets of trucks usually purchase gasoline, lubricants and tires at wholesale prices.

Before anyone can tell a prospective purchaser how much it will cost a day to operate a motor truck, it is, in our opinion, very important that he be in possession of all operating facts. In order that we may establish a definite policy, we have succeeded in getting out charts which represent the cost of motor vehicles of Packard make from one to one and a half ton to six tons inclusive. A set of these is reproduced.

We believe that these figures represent as nearly as possible the actual cost of operating a Packard motor truck, providing the operating conditions are similar to the ones these charts are based on. Should you find an occasion to use any of these operating cost charts, it is requested you mention that the figures given will not apply in all localities. They are chiefly valuable as a guide to show how costs are worked out. You will note on the operating cost charts, under interest, that we used the National Standard Truck formula for computing interest. This formula is far superior to the old method of computing interest by compounding same."

This writer also recommends the National Truck Cost System as the best method of keeping records of operating costs of trucks. Readers interested in this system can procure full information by writing the Truck Owners Conference, Inc., Chicago, Ill. It is exceptionally complete, and should be of great value as everything is so clearly explained and the forms are so simple that any clerk can keep up the system.

PACKARD 1½-1¾ TON TRUCK

Investment

Chassis	$3,200.00
Freight	55.00
War Tax	74.40
Body, Top, etc.	350.00
Total (Basis for Computing Interest)	$3,679.40
Less tire value	203.16
Sinking Fund	$3,476.24

New York City and vicinity.
Second insurance classification.
Operating 300 days per annum.

Insurance

Fire and Theft	$ 39.05
Collision, full coverage	139.00
Liability	285.00
Property Damage	125.40
Total	$588.45

Sinking Fund

$3,476.24 ÷ 100,000 miles = 3.476 cents per mile.

Interest

Use National Standard Truck Cost Formula.

$$\frac{A+1}{A} \times \frac{C \times B}{2}$$

Wherein A equals sinking fund period or expected life of truck; B equals investment; C equals interest rate.

Gasoline

MILES PER GALLON

Good	Average	Fair
7.5	7	6

OPERATING COST PER DAY

Miles per Day	20	30	40	50	60
Garage	$1.00	$1.00	$1.00	$1.00	$1.00
Driver	5.00	5.00	5.00	5.00	5.00
Taxes	.08	.08	.08	.08	.08
Insurance	1.96	1.96	1.96	1.96	1.96
Sinking Fund	.70	1.04	1.39	1.74	2.09
Interest	.37	.38	.39	.40	.41
Gasoline*	.77	1.16	1.54	1.93	2.31
Lubrication†	.12	.18	.24	.30	.35

* "Average" miles per gallon used in computation.
† "Necessary" lubrication used in computation.

Miles per Day	20	30	40	50	60
Tires	.41	.61	.81	1.15	1.22
Maintenance and Overhaul	.45	.68	.90	1.13	1.35
Total Cost per Day	10.86	12.09	13.31	14.69	15.77
Total Cost per Year	3258.00	3627.00	3993.00	4407.00	4731.00
Total Cost per Mile	.54	.40	.33	.29	.26

LUBRICATION PER 1,000 MILES

(Includes Refilling)

	Necessary		Desirable	
	Gallons	Cost	Gallons	Cost
Cylinder Oil @ .70 per gal.	6.25	$4.375	8.333	$5.83
Heavy Oil @ .80 per gal.	1.25	1.00	1.666	1.333
Grease @ .17 per lb.	3.333	.568	5.	.85
Cost per Mile		.0059		.008

Maintenance and Overhaul

Total cost of maintenance and overhaul during operation over 100,000 miles estimated at $2.250.00 or 2.25 cents per mile.

Tires

$203.16 ÷ 10,000 miles = 2.03 cents per mile.

Miscellaneous

State License	$25.00
Garage Rent per Month	25.00
Driver's Wages per Day	5.00
Gasoline per Gallon	.27
Guaranteed Tire Mileage 10,000	

PACKARD 2-2½ TON TRUCK

Investment

Chassis	$3,600.00
Freight	70.00
War Tax	83.70
Body, Top, etc.	400.00
Total (Basis for Computing Interest)	$4,153.70
Less tire value	233.64
Sinking Fund	$3,920.06

Operating Conditions

New York City and vicinity.
Second insurance classification.
Operating 300 days per annum.

Insurance

Fire and Theft	$ 45.69
Collision, full coverage	148.00
Liability	285.00
Property Damage	125.40
Total	$604.09

Sinking Fund

$3,920.06 ÷ 100,000 miles = 3.92 cents per mile.

Interest

Use National Standard Truck Cost Formula previously given.

Gasoline

MILES PER GALLON

Good	Average	Fair
7	6.5	5.5

OPERATING COST PER DAY

Miles per Day	20	30	40	50	60
Garage	$1.00	$1.00	$1.00	$1.00	$1.00
Driver	5.00	5.00	5.00	5.00	5.00
Taxes	.10	.10	.10	.10	.10
Insurance	2.01	2.01	2.01	2.01	2.01
Sinking Fund	.78	1.17	1.47	1.96	2.34
Interest	.44	.47	.48	.50	.52
Gasoline*	.83	1.24	1.66	2.08	2.49
Lubrication†	.12	.18	.24	.30	.35
Tires	.47	.70	.93	1.17	1.40
Maintenance and Overhaul	.50	.75	1.00	1.25	1.50
Total Cost per Day	11.25	12.62	13.89	15.37	16.71
Total Cost per Year	3375.00	3786.00	4167.00	4611.00	5013.00
Total Cost per Mile	.56	.41	.35	.31	.28
Total Cost per					

* "Average" miles per gallon used in computation.
† "[illegible]" lubrication used in computation.

LUBRICATION PER 1,000 MILES

(Includes Refilling)

	Necessary		Desirable	
	Gallons	Cost	Gallons	Cost
Cylinder Oil @ .70 per gal.	6.25	$4.375	8.333	$5.83
Heavy Oil @ .80 per gal.	1.25	1.00	1.666	1.333
Grease @ .17 per lb.	3.333	.568	5.	.85
Cost per Mile		.0059		.008

Maintenance and Overhaul

Total cost of maintenance and overhaul during operation over 100,000 miles estimated at $2,500.00 or 2.5 cents per mile.

Tires

$233.64 ÷ 10,000 miles = 2.33 cents per mile.

Miscellaneous

State License	$30.00
Garage Rent per Month	25.00
Driver's Wages per Day	5.00
Gasoline per Gallon	.27

Guaranteed Tire Mileage 10,000

PACKARD 3-3½ TON TRUCK

Investment

Chassis	$4,350.00
Freight	70.00
War Tax	101.14
Body, Top, etc.	500.00
Total (Basis for Computing Interest)	$5,021.14
Less tire value	312.48
Sinking Fund	$4,708.66

Operating Conditions

New York City and vicinity.

Second insurance classification.

Operating 300 days per annum.

Insurance

Fire and Theft	$ 53.35
Collision, full coverage	159.00
Liability	285.00
Property Damage	125.40
Total	$622.75

Sinking Fund

$4,708.66 ÷ 100,000 miles = 4,708 cents per mile.

Interest

Use National Standard Truck Cost Formula.

Gasoline

MILES PER GALLON

Good	Average	Fair
5.5	4.8	4.3

OPERATING COST PER DAY

Miles per Day	20	30	40	50	60
Garage	$1.00	$1.00	$1.00	$1.00	$1.00
Driver	5.00	5.00	5.00	5.00	5.00
Taxes	.13	.13	.13	.13	.13
Insurance	2.08	2.08	2.08	2.08	2.08
Sinking Fund	.94	1.41	1.88	2.35	2.82
Interest	.53	.55	.56	.59	.60
Gasoline*	1.12	1.69	2.25	2.87	3.37
Lubrication†	.16	.23	.31	.39	.47
Tires	.62	.94	1.25	1.56	1.87
Maintenance and Overhaul	.60	.90	1.20	1.50	1.80
Total Cost per Day	12.18	13.93	15.66	17.41	19.14
Total Cost per Year	3654.00	4179.00	4698.00	5223.00	5742.00
Total Cost per Mile	.61	.48	.39	.35	.31

LUBRICATION PER 1,000 MILES

(Includes Refilling)

	Necessary		Desirable	
	Gallons	Cost	Gallons	Cost
Cylinder Oil @ .70 per gal.	8.33	$5.83	10.41	$7.28
Heavy Oil @ .80 per gal.	1.666	1.333	2.5	2.00
Grease @ .17 per lb.	3.75	.64	5.41	.92
Cost per Mile		.0078		.0102

Maintenance and Overhaul

Total cost of maintenance and overhaul during operation over 100,000 miles estimated at $3,000 or 3 cents per mile.

Tires

$312.48 ÷ 10,000 miles = 3.124 cents per mile.

Miscellaneous

State License	$40.00
Garage Rent per Month	25.00
Driver's Wages per Day	5.00
Gasoline per Gallon	.27
Guaranteed Tire Mileage 10,000	

* "Average" miles per gallon used in computation.

† "Necessary" lubrication used in computation.

PACKARD 4-4½ TON TRUCK

Investment

Chassis	$4,550.00
Freight	70.00
War Tax	105.79
Body, Top, etc.	500.00
Total (Basis for Computing Interest)	$5,225.79
Less tire value	327.56
Sinking Fund	$4,898.23

Operating Conditions

New York City and vicinity.
Second insurance classification.
Operating 300 days per annum.

Insurance

Fire and Theft	$ 59.48
Collision, full coverage	168.00
Liability	285.00
Property Damage	125.40
Total	$637.88

Sinking Fund

$4,898.23 ÷ 100,000 miles = 4.898 cents per mile.

Interest

Use National Standard Truck Cost Formula.

$$\frac{A + 1}{A} \times \frac{C \times B}{2}$$

Wherein A equals sinking fund period or expected life of truck; B equals investment; C equals interest rate.

Gasoline

MILES PER GALLON

Good	Average	Fair
5	4.4	4

OPERATING COST PER DAY

Miles per Day	20	30	40	50	60
Garage	$1.00	$1.00	$1.00	$1.00	$1.00
Driver	5.00	5.00	5.00	5.00	5.00
Taxes	.17	.17	.17	.17	.17
Insurance	2.13	2.13	2.13	2.13	2.13
Sinking Fund	.98	1.47	1.96	2.45	2.94
Interest	.55	.57	.59	.61	.63
Gasoline*	1.23	1.84	2.45	3.06	3.68
Lubrication†	.16	.23	.32	.39	.48
Tires	.66	.98	1.31	1.32	1.97
Maintenance and Overhaul	.65	.98	1.30	1.63	1.95

* "Average" miles per gallon used in computation.

† "Necessary" lubrication used in computation.

Miles per Day	20	30	40	50	60
Total Cost per Day	12.53	14.37	16.23	17.76	19.95
Total Cost per Year	3759.00	4311.00	4859.00	5328.00	5985.00
Total Cost per Mile	.63	.48	.41	.36	.33

LUBRICATION PER 1,000 MILES

(Includes Refilling)

	Necessary		Desirable	
	Gallons	Cost	Gallons	Cost
Cylinder Oil @ .70 per gal.	8.33	$5.83	10.41	$7.28
Heavy Oil @ .80 per gal.	1.666	1.333	2.5	2.00
Grease @ .17 per lb.	3.75	.64	5.41	.92
Cost per Mile		.0078		.01

Maintenance and Overhaul

Total cost of maintenance and overhaul during operation over 100,000 miles estimated at $3,250.00 or 3.25 cents per mile.

Tires

$327.56 ÷ 10,000 miles = 3.275 cents per mile.

Miscellaneous

State License	$50.00
Garage Rent per Month	25.00
Driver's Wages per Day	5.00
Gasoline per Gallon	.27
Guaranteed Tire Mileage 10,000	

PACKARD 5-5½ TON TRUCK

Investment

Chassis	$5,450.00
Freight	80.00
War Tax	126.71
Body, Top, etc.	700.00
Total (Basis for Computing Interest)	$6,356.71
Less tire value	398.90
Sinking Fund	$5,957.81

Operating Conditions

New York City and vicinity.
Second insurance classification.
Operating 300 days per annum.

Insurance

Fire and Theft	$ 69.92
Collision, full coverage	174.00
Liability	285.00
Property Damage	125.40
Total	$654.32

Sinking Fund

$5,957.85 ÷ 100,000 miles = 5.957 cents per mile.

Interest

Use National Standard Truck Cost Formula.

Gasoline

MILES PER GALLON

Good	Average	Fair
4.5	3.8	3

OPERATING COST PER DAY

Miles per Day	20	30	40	50	60
Garage	$1.00	$1.00	$1.00	$1.00	$1.00
Driver	5.00	5.00	5.00	5.00	5.00
Taxes	.18	.18	.18	.18	.18
Insurance	2.18	2.18	2.18	2.18	2.18
Sinking Fund	1.19	1.79	2.38	2.98	3.57
Interest	.68	.69	.71	.74	.76
Gasoline*	1.42	2.13	2.80	3.55	4.26
Lubrication†	.20	.31	.41	.51	.61
Tires	.80	1.20	1.60	2.00	2.40
Maintenance and Overhaul	.75	1.13	1.50	1.88	2.25
Total Cost per Day	13.40	15.61	17.76	20.02	22.21
Total Cost per Year	4020.00	4683.00	5328.00	6006.00	6663.00
Total Cost per Mile	.67	.52	.44	.40	.37

LUBRICATION PER 1,000 MILES

(Includes Refilling)

	Necessary		Desirable	
	Gallons	Cost	Gallons	Cost
Cylinder Oil @ .70 per gal.	10.833	$7.58	14.58	$10.21
Heavy Oil @ .80 per gal.	2.5	2.00	3.333	2.67
Grease @ .17 per lb.	4.166	.71	6.25	1.06
Cost per Mile		.0102		.0139

* "Average" miles per gallon used in computation.

† "Necessary" lubrication used in computation.

Maintenance and Overhaul

Total cost of maintenance and overhaul during operation over 100,000 miles estimated at $3,750.00 or 3.75 cents per mile.

Tires

$398.90 ÷ 10,000 miles = 3.989 cents per mile.

Miscellaneous

State License	$55.00
Garage Rent per Month	25.00
Driver's Wages per Day	5.00
Gasoline per Gallon	.27
Guaranteed Tire Mileage 10,000	

PACKARD 6-6½ TON TRUCK

Investment

Chassis	$5,700.00
Freight	80.00
War Tax	132.53
Body, Top, etc.	700.00
Total (Basis for Computing Interest)	$6,612.53
Less tire value	465.06
Sinking Fund	$6,147.47

Operating Conditions

New York City and vicinity.
Second insurance classification.
Operating 300 days per annum.

Insurance

Fire and Theft	$ 72.74
Collision, full coverage	179.00
Liability	285.00
Property Damage	125.40
Total	$662.14

Sinking Fund

$6,147.47 ÷ 100,000 miles = 6.147 cents per mile.

Interest

Use National Standard Truck Cost Formula.

Gasoline

MILES PER GALLON

Good	Average	Fair
4.2	3.3	2.5

OPERATING COST PER DAY

Miles per Day	20	30	40	50	60
Garage	$1.00	$1.00	$1.00	$1.00	$1.00
Driver	5.00	5.00	5.00	5.00	5.00

Miles per Day	20	30	40	50	60
Taxes	.20	.20	.20	.20	.20
Insurance	2.21	2.21	2.21	2.21	2.21
Sinking Fund	1.23	1.84	2.46	3.07	3.69
Interest	.70	.72	.74	.77	.79
Gasoline*	1.76	2.63	3.41	4.39	5.27
Lubrication†	.20	.31	.40	.51	.60
Tires	.93	1.40	1.86	2.33	2.79
Maintenance and Overhaul	.80	1.20	1.60	2.00	2.40
Total Cost per Day	14.03	16.51	18.88	21.48	23.95
Total Cost per Year	4209.00	4953.00	5664.00	6444.00	7185.00
Total Cost per Mile	.70	.55	.47	.43	.40

LUBRICATION PER 1,000 MILES

(Includes Refilling)

	Necessary		Desirable	
	Gallons	Cost	Gallons	Cost
Cylinder Oil @ .70 per gal.	10.833	$7.58	14.58	$10.21
Heavy Oil @ .80 per gal.	2.5	2.00	3.333	2.67
Grease @ .17 per lb.	4.166	.71	6.25	1.06
Cost per Mile		.0102		.0139

Maintenance and Overhaul

Total cost of maintenance and overhaul during operation over 100,000 miles estimated at $4,000 or 4 cents per mile.

Tires

$465.06 ÷ 10,000 miles = 4.65 cents per mile.

Miscellaneous

State License	$60.00
Garage Rent per Month	25.00
Driver's Wages per Day	5.00
Gasoline per Gallon	.27

Guaranteed Tire Mileage 10,000

* "Average" miles per gallon used in computation.

† "Necessary" lubrication used in computation.

THE TON-MILE BASIS FOR COST FIGURES

The Ton-Mile, Package-Mile, the M-Foot-Mile, etc., and How to Figure Them.

SYDNEY S. MERITHEW

Reprinted from One-Hundred Per Cent Magazine

Cost figures, when properly compiled, furnish one of the only reliable bases from which to improve any service. Particularly is this true of transportation systems and delivery service. These figures must also be brought to the same level to be of any service for comparison. This last statement, in itself, must be carefully considered, for it is common practice to make all sorts of comparisons, disregarding all the conditions surrounding the things to be compared. The ton-mile and its different varied forms, of which the package-mile, the M-foot-mile and the delivery-mile are but the more important, is but the result of getting a common basis for making comparisons.

But again, it should be known and appreciated that when the ton-mile basis is attained it may be affected to a great extent by other conditions. To illustrate: If the conditions surrounding a delivery employing two trucks of the same capacity are identical except in the number of miles which each travels, the ton-mile cost will not be the same. The table below, taken from standard cost figures, will prove this. From this table we can see that increasing the daily mileage in this case from 15 to 60 miles has reduced our ton-mile cost over 57 per cent. Of course, there is a reason for this.

The Reason.—Truck costs as generally figured are of two kinds: Fixed—those which must be paid every day, even if the truck stands idle all day; and Variable—those which depend on the work which the truck performs. The cost of any work performed by the truck consists of the fixed and variable charges for the time required to do the work.

The fixed charge is the same regardless of mileage, so the fixed charge per mile will depend on the number of miles.

Suppose the fixed charge is $4.00 per day. Now, if the daily mileage is 20, the charge per mile will be $0.20, but if the mileage is 40, the charge per mile will be only $0.10. Let us assume the variable charge to be $0.07 per mile. Then in the two cases above we have a mileage charge of $0.27 and $0.17, respectively.

Relation of Miles and Ton-Miles.—Through some misunderstanding, ton-miles are figured in almost as many ways as there are companies figuring, and it is our purpose to show the basis on which ton-miles must be figured to be correct. Defined, a ton-mile is the carrying of one ton one mile. Similarly, the package-mile is the carrying of a package one mile, and the M-foot-mile is the carrying of M feet one mile. Obviously, the ton mile is the most convenient unit for the coal dealer, a contractor or a miller; the package-mile is equally suited to the express company or the department store, while the lumber dealer will find the M-foot-mile of most use. A five-ton truck loaded to capacity will accomplish five ton-miles in going one mile. Ton-miles then depend on the miles traveled and the load carried. It is very essential to get the proper relation of these two items if we want a proper unit cost.

Some users have multiplied the miles traveled per day by the total weight in tons carried that day. This might be right if the truck made but one trip, but if more trips were made this result should be divided by the number of trips. Even this result represents the ideal condition and not an average one.

There are at least three hauling conditions:

Full load basis:—

$$(1)\quad \text{Miles per trip} \times \text{Total} \left\{\begin{matrix}\text{tons}\\ \text{packages}\\ \text{M-feet}\end{matrix}\right\} \text{per day} = \left\{\begin{matrix}\text{ton}\\ \text{package}\\ \text{M-foot}\end{matrix}\right\} \text{Miles}$$

or

$$(2)\quad \text{Miles per day} \times \text{Average} \left\{\begin{matrix}\text{tons}\\ \text{packages}\\ \text{M-feet}\end{matrix}\right\} \text{per trip} = \left\{\begin{matrix}\text{ton}\\ \text{package}\\ \text{M-foot}\end{matrix}\right\} \text{Miles}$$

Half load basis:—

$$(3)\quad \frac{\text{Miles per trip}}{2} \times \text{Total} \left\{\begin{matrix}\text{tons}\\ \text{packages}\\ \text{M-feet}\end{matrix}\right\} \text{per day} = \left\{\begin{matrix}\text{ton}\\ \text{package}\\ \text{M-foot}\end{matrix}\right\} \text{Miles}$$

or

$$(4)\quad \frac{\text{Miles per day}}{2} \times \text{Average} \left\{\begin{matrix}\text{ton}\\ \text{package}\\ \text{M-feet}\end{matrix}\right\} \text{per trip} = \left\{\begin{matrix}\text{ton}\\ \text{package}\\ \text{M-foot}\end{matrix}\right\} \text{Miles}$$

Fractional load basis:—

$$(5)\quad \frac{\text{Miles per trip}}{\text{Total Miles} \div} \times \begin{matrix}\text{Total}\\ \text{Loaded}\\ \text{Miles}\end{matrix} \left\{\begin{matrix}\text{tons}\\ \text{packages}\\ \text{M-feet}\end{matrix}\right\} \text{per day} = \left\{\begin{matrix}\text{ton}\\ \text{package}\\ \text{M-foot}\end{matrix}\right\} \text{Miles}$$

$$(6)\quad \frac{\text{Miles per day}}{\text{Total Miles} \div} \times \begin{matrix}\text{Average}\\ \text{Loaded}\\ \text{Miles}\end{matrix} \left\{\begin{matrix}\text{tons}\\ \text{packages}\\ \text{M-feet}\end{matrix}\right\} \text{per trip} = \left\{\begin{matrix}\text{ton}\\ \text{package}\\ \text{M-foot}\end{matrix}\right\} \text{Miles}$$

Carrying a capacity load the entire length of a round trip.

Carrying a capacity load to a given point and returning empty.

Carrying a capacity load out and returning with a partial load.

Starting with a capacity load and distributing it over the entire round trip may be considered in the second group.

Each of these conditions should be figured differently, and we believe the following methods correct. The first we will call "full load" basis; the second, "half load" basis, and the third, "three-quarter or fractional" basis.

Figuring on the Basis.—In figuring on the "full load" basis, every mile of travel is represented by an actual load, and so the cost can be equally distributed over the entire mileage. On the "half load" basis only half the mileage is represented by a load, and so the loaded miles must pay for the empty miles. Also on the "three-quarter or fractional" basis only a part of the entire miles traveled are represented by a capacity load, and these empty miles must be paid by the loaded miles.

A formula for figuring these conditions can be expressed in either of two ways. By trips we mean round trips.

A single example will prove that either formula will produce the same result.

A 1½-ton truck makes four trips a day, travels 60 miles, and carries a capacity load both ways. How many ton-miles are represented?

The round trip distance equals 15 miles. Then by formula number (1) 15 (miles) × (4 × 1.5 tons) = 90 ton-miles.

And by formula number (2):

60 (miles) × 1.5 tons = 90 ton-miles.

Let us suppose that this truck only carried a load one way. Now if we want to find the correct ton-miles we must either use formula 3 or 4. Using (3) we will get:

$$\frac{15}{2} \times (4 \text{ x } 1.5 \text{ tons}) = 45 \text{ ton-miles.}$$

It will be noted that this result is one-half that found under the "full load" basis. The ton-mile cost will be double that of the "full load" basis, and this is right, for the loaded miles must pay for the empty ones.

Again let us suppose that this same truck went out with a full load and returned with a half load. The correct ton-mileage can be found by the use of either formula (5) or (6). Using (6) the result will be:

$$\frac{60}{60 \div 45} \times 1.5 = 67.5 \text{ ton miles.}$$

Cost Per Ton-Mile.—Figuring the cost per ton-mile is a simple matter when once the number of ton-miles is known, providing our costs are right. Costs, however, are not a part of this article. The single statement that, if the daily cost and the ton-miles are known, simple division will give the ton-mile cost, may be of interest in closing this article.

BONUS SYSTEMS

GEO. W. VEALE, Director, Dept. of Standards,

Timken-Detroit Axle Co., Detroit

A very practical way of increasing the efficiency of motor truck use is to establish a bonus for the drivers and helpers. The ideal to accomplish in such a plan is precisely the same as that in the payment of bonuses for shop performance. Through encouraging individual effort, the efficiency of the truck operation is greatly increased, both as to accomplishment and cost. Almost any bonus or premium plan can be applied to the operation of the motor trucks after having found a satisfactory unit for gauging standard performance.

Care must be taken in establishing the bonus plan to make sure that only such items as are under the operator's control are included, therefore it is not practicable to use the TOTAL COST where this is intended to include taxes, interest on investment, regular depreciation, etc. These items are generally handled on a yearly basis, which makes the monthly charge the same under all conditions, regardless of the performance. If, therefore, such items are included in the standard for the operator's bonus plan, they are likely to have undue influence, and at times make the plan ineffective.

In a business where it is measurable the best unit for comparing accomplishments seems to be the PER TON-MILE, which simply means the hauling of one ton mile; if you take one ton five miles you will have five ton-miles, and, likewise, if you carry five tons one mile you will get the same—five ton-miles. This unit, coupled with the cost over which the operator has control, gives the best basis for establishing motor trucking on a bonus plan. Where irregular hauling problems make it difficult to secure ton-miles, package-miles or other units may be substituted.

The driver is directly responsible to a large degree for all of the items listed below, and should therefore be given the opportunity of personal gain through his efficient use of them:

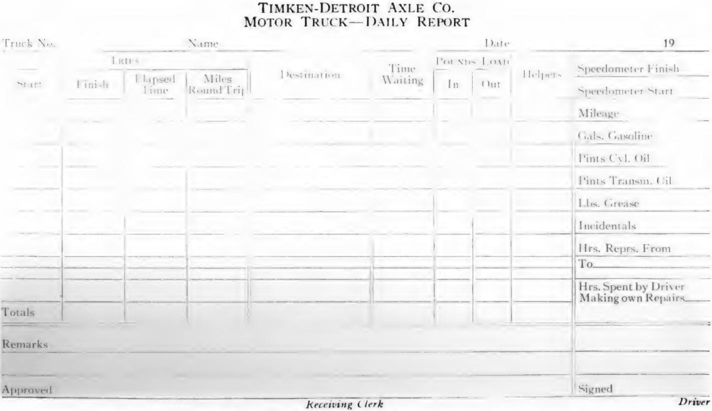
1. Miles Traveled.
2. Pounds Carried.
3. Time Consumed.
4. Wages of Driver and Helper.
5. Tire Expense.
6. Maintenance Expense.
7. Gasoline, Oil and Grease.
8. Time in Service.
9. Time Waiting for Loading and Unloading.

Several of these items are only contributory, but as such they have an effect upon the final unit cost.

The use of daily trip report records is established showing the performance on all of the above items, which form a basis for determining a standard cost. (Fig. 523.) These records should be summarized by individual trucks. (Fig. 524.)

It is then necessary to transform these individual truck monthly records into a combined statement. For this purpose, several more headings have been found useful. All headings are listed below, because the statement itself is not in readily reducible form:

Asset Account No.
Truck Name.
Gals. Cylinder Oil.
Gallons Gasoline.
Average Miles Per Trip.
Gals. Anti-Freeze.
Repairs, Material and Labor.
Operating Labor.
Total Expense.
Operating Hours.
Idle Hours.
Out of Service Hours.
Total Hours.
Per Cent Operating.
Number of Trips.
Average Hours Per Trip.
Total Miles.
Gals. Transmission Oil.
Total Load in Pounds.
Load per Trip in Tons.
Ton-Miles per Trip.
Total Ton-Miles.
Hours per Ton-Mile.
Miles per Gal. of Gas.
Gals. Gas per T. M.
Total Expense per T. M.



TIMKEN-DETROIT AXLE CO.
MOTOR TRUCK—DAILY REPORT

Truck No. ____ Name ____ Date ____ 19__

Trips				Destination	Time Waiting	Pounds Load		Helpers	
Start	Finish	Elapsed Time	Miles Round Trip			In	Out		Speedometer Finish
									Speedometer Start
									Mileage
									Gals. Gasoline
									Pints Cyl. Oil
									Pints Transm. Oil
									Lbs. Grease
									Incidentals
									Hrs. Reprs. From
									To
									Hrs. Spent by Driver Making own Repairs
Totals									

Remarks

Approved ____ *Receiving Clerk* Signed ____ *Driver*

Fig. 523.—Daily Trip Report on which Drivers Record Detailed Data of Performance.

Fixing Standards.—Of course, the hard work is done at first when you establish your standards. It takes a good deal of time to do that, but once that is done the application of the schedule is fairly simple. The establishment of the standards is really not so difficult, either, but it is something that varies with each problem. In the first place, you study out what factors are involved. Does your loading time depend upon the transferring of the material inside of the plant, does it depend upon electric tractors, men transferring the material by hand, or what are the controlling factors? After you have determined what factors are controlling the loading time, then, of course, you can easily make your statistical studies and fix the allowable time for each factor.

The determination, of course, can be as scientific as you care to make it, but, on the other hand, it has to be practical enough to be able to supply it. We have been compelled to eliminate a number of factors that we knew existed, and if we wanted to go to the extreme of including those factors, we could, but if we did that, the application of the bonus plan would be so involved that it would take more time than it was worth, and inasmuch as our plan includes the payment of bonuses over a period of two weeks, any little discrepancy would average up over a two weeks' period. The original study, of course, is the more important. After that, for my part, I don't believe it makes much difference how you pay the bonus. I know it is very simple to apply your bonus or premiums in different ways, depending upon what plan you like to follow—there is the Rowan Plan, the Taylor Differential Plan, the Straight Rate Plan. It is a question of which one you care to use, and which appeals to you to be the most just. In fact, we have our own modifications even with the Emerson Plan. The plan that you use is not really the most important feature—it is the idea of some sort of an incentive to the men that makes it worth while for them to take an interest.

One Method.—A simple plan would be merely to divide the savings with the men. That is being done a great deal in straight manufacturing, where the savings in time are divided 50-50 with the men. In fact, on some of our more unstandardized operations we are doing that to a certain extent in connection with the Emerson System.

I might say this about the Emerson basis: it is the most complete, as far as application is concerned; that is, the system is absolutely covered and no allowances need be made, and no general percentage of allowances is necessary. And it is also the most generous. For each increase of any efficiency at all the man makes he gets a bigger reward. In some of the places where we have found it difficult just at this time to make all the improvements we expect to make, or sometimes where it would take a long time, many years, probably, to study all the factors we know exist, and where the operation probably affects only one man—we have had cases like that—in those cases we don't make the complete, intensive study of the operation, but we do make one sufficient to give us the general information. In such cases we go to the man and we say, "Here, we are going to study this operation, we are going to make a complete and intensive study of it in time, but right now we have not been able to, but we have a basis which we think is fairly correct and we are going to give you a standard basis on our studies up to date and we are going to divide 50-50 with you," which, in such cases, would be 50 per cent of the Emerson Curve. He knows then that he has opportunities later for a bigger reward, and he co-operates with us in getting the whole information.

The Three Factors in Bonus Systems.—A bonus is not paid for quantity merely; there is need to be watchful for quality, especially today, when a fight is going on against avoidable wastage of all kinds.

Another danger in awarding bonus that must be guarded against is the possibility of workers producing at top speed at the beginning of the week, and slacking at the end, because they have earned a good round sum and do not care for more at the expense of too great effort. The third factor is production; after quantity and quality is steadiness.

After sufficient records have accumulated to give average conditions a standard can be determined.

A maximum is then set, and the drivers and helpers are offered a bonus of 50 PER CENT OF THE SAVING under the maximum established.

The efficiency of performance is determined by dividing the standard cost by the actual.

EXAMPLE

a. Standard Cost per Ton-Mile = \$0.05
b. Maximum Cost per Ton-Mile = 0.075
c. Operator's Actual Cost per Ton-Mile = 0.06
d. Total. Ton-Miles Accomplished = 1800

The driver's bonus is determined by the formula b—c
Xd
= bonus, which in this case would be:
2

$$\frac{.075 - .06}{2} \times 1800 = \$13.50.$$

The efficiency is represented by $\frac{a}{c}$ = efficiency;

in this case $\frac{5}{6}$ = 83.33 per cent.

This may appear as a rather high reward for an efficiency of only 83.33 per cent, but it will be found that, with unstandardized conditions and no efficiency reward, costs will be very much higher than even the maximum set, and that high reward will encourage high accomplishment.

After applying the method for a period of eight months in our business, it has resulted in increased loads (without overloading) higher percentage of operating time, and decreased cost.

The actual accomplishment on several trucks on a similar class of work and on the bonus plan described herein is shown below:

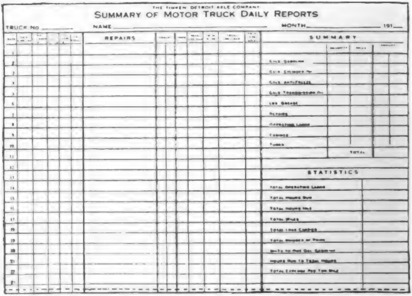
Trucks Number	Ton-Miles per Month Per Cent Gain	Cost per Ton-Mile Per Cent Decrease
1	45.4%	43.7%
2	5.5%	13.8%
3	3.5%	29.8%
4	1.5%	11.5%

The plan discourages abuses of all kinds and encourages careful driving and "safety first." In case of accident the expense for repairs is charged against the driver's cost, unless he is clearly not at fault.

Heavy items, such as new tires and general overhauling, must be spread over a period equivalent to their average life.

Weather conditions affect greatly the efficient operating of motor trucks, and it is therefore advisable to figure the accomplishment over a period of six months to one year (on a simple individual truck summary card), so as to average out conditions of bad weather. If this is not done it will be necessary to establish a WINTER standard.

The TOTAL TON-MILES can be determined daily and accumulated at the end of the month, or the result can be found by obtaining the average load per trip in tons and multiplying by the average miles per trip. The latter method is preferable for the bonus plan, as it will make sure that all light loads have been included.



THE TIMKEN DETROIT AXLE COMPANY

SUMMARY OF MOTOR TRUCK DAILY REPORTS

TRUCK NO ________ NAME ________________________ MONTH ________________ 191__

REPAIRS

SUMMARY

TOTAL

STATISTICS

Fig. 524.—Individual Truck Summary. One for Each Machine, Covering a Month's Operation.

Poor Economy in Towing Horse Wagons.—It is but natural that owners of heavy horse trucks, which cost a good deal to build and are particularly difficult to dispose of, should seek to round out the lives of their wagons by using them as appendages to their motor equipment — in other words, as trailers. There still are a good many wagon builders who have not had sufficient experience to show them how lamentably frail even a heavy horse truck proves to be when used as a trailer with a motor truck.

While the work on a big horse truck may sometimes appear to be somewhat crude and perhaps unnecessarily massive, it is in reality nothing of the sort. Usually there is very little done in the way of calculation of stresses in a wagon shop, but the piling of experience upon experience has resulted in a sort of standardization that is quite accurate and satisfactory. When a wagon builder has to turn out a job he refers to other jobs that have been used under approximately like conditions, and he can tell to a nicety just what to put into his work. If he finds a record of a broken axle, or settled springs, or sprung wheels on a job of about the size he has in mind, he adds a little to his dimensions, or specifies a better grade of material, and goes ahead with an easy mind. Because he has done the same thing before so often, he knows just what the result will be.

When a horse truck is attached to the rear end of a motor truck, however, conditions are so altered that trouble is almost inevitable. A little analysis will show why. A bearing that is designed to run at a given speed under a given load will—or ought to—run through its normal life with a minimum of attention and without giving trouble. The bearings upon which truck wheels run are designed for a slow speed. A good average speed for a heavy truck is 2½ miles an hour, and at this speed a five-foot wheel makes about 14 revolutions per minute. If it runs any faster than this under load it is only for very brief periods; horses are not capable of overspeeding these bearings.

Attach the truck to a tractor, however, and the conditions are radically altered. With plenty of power ahead, there is little likelihood of unloading; the chances are more favorable for a load greater than normal, for there are no horses to worry about. Assume a normal load, however, and at once the question of speed intrudes. It is safe to figure that the normal speed of the tractor will be not less than seven or eight miles an hour. That is to say, the speed will be trebled. The wheels, instead of turning at 14 revolutions per minute, will turn about 42 revolutions per minute. Now 42 revolutions per minute sounds like a very slow speed, but it is actually an increase of 200 per cent. There are not many bearings, designed within fairly close limits, that will run satisfactorily at such a tremendous increase. Certainly truck axle bearings will rarely do it. Not only is the wear increased at least 200 per cent, but the demand for lubrication is increased even more, because of the tendency to heating, and the average truck bearings simply will not lubricate satisfactorily at such speed. Any doubting Thomas can satisfy himself by the somewhat grimy expedient of putting his hand on the axle end of a heavily loaded horse truck that has been on the road for some time under its normal motive power. Four chances to five there will be a perceptible warming of the metal. It does not require much imagination to forecast the effect of a speed 200 per cent above normal.

No small part of the traveling of such trucks is done over roads paved with rough stone blocks, and the difference in the effects of the vibration at 2½ miles an hour and eight miles an hour is enormous. At the slower speeds the horse truck merely climbs the bumps and settles into the hollows with a comparatively easy motion. At the higher speeds, the tires actually bounce from peak to peak with a series of hammer-like blows. and the result is destructive to the whole of the construction. In two directions particularly are the effects apparent. The constant banging weakens the axle, and breakages occur at the shoulder where the journal joins the axle proper. Axle breakages also are apt to occur at this point through failure of lubrication, causing the box to freeze on the journal. If the axle is abnormally strong the result may be merely to slide the wheel, but not many axles will stand much of this sort of treatment. An indication of the intensity of the forces involved is found in the fact that brass boxes have been partly fused in heavy horse trucks used as trailers and run under the loads they were designed for but at speeds of about nine miles an hour.

Steel tires suffer from such service. The hammering action out in splinters; the tires are peened, so to speak, and enlarged and loosened. Also the tremendous energy that must be contended with often crystallizes the steel tire.

The wheels themselves often feel the effects of high speeds before anything else, and the first indication is a slight cracking creak which, at first occurring in a single spoke, soon spreads until the wheel groans and crackles through its complete revolution. When a wheel complains in this way there is little or no hope for it; it simply is too weak for the work, and it is merely a question of judgment as to how long it can be run before it fails. Tightening up or repairing such wheels is a waste of time, unless the looseness is caused by excessive dryness. Usually this is not the case.

Springs seem to suffer less than other parts of a truck used as a trailer, probably because they are made primarily to stand up under heavy work, and only secondarily as shock absorbers. The clips, however, are rather likely to be points of weakness, not only through breakage, but through loosening up under the fierce vibration.

That horse trucks will not stand up under trailer service, as a rule, is not an indication of weakness; it simply means that they will not do two or three times the work they were built to do without wearing out two or three times faster. This is perfectly logical, for a truck built several times stronger than necessary for its normal work would be needlessly expensive and heavy.

Obstacles to Manufacturers' Inspection.—Truck manufacturers in some instances have made provision for inspection of machines at the service stations of branches or dealers, and have developed organizations that are intended to do this with regularity, but these have been only reasonably successful because owners frequently believe that such examinations are proposed because the manufacturers are suspicious of the use made of machines and seek evidence that will justify evasion of responsibility for guarantee made in the sales contract, or the owners assume that the degree of care recommended is not necessary.

Manufacturer's and Dealer's Service.—The J. W. Maguire Co., Boston, agent for New Hampshire and eastern Massachusetts for Pierce-Arrow trucks, is now operating a system inaugurated more than three years ago, and which, while independent of, is coordinated with, the service of the Pierce-Arrow company's which is general the country over, but that of the Maguire company is localized in the territory specified, and its dealings are direct with the owners and not through the factory organization.

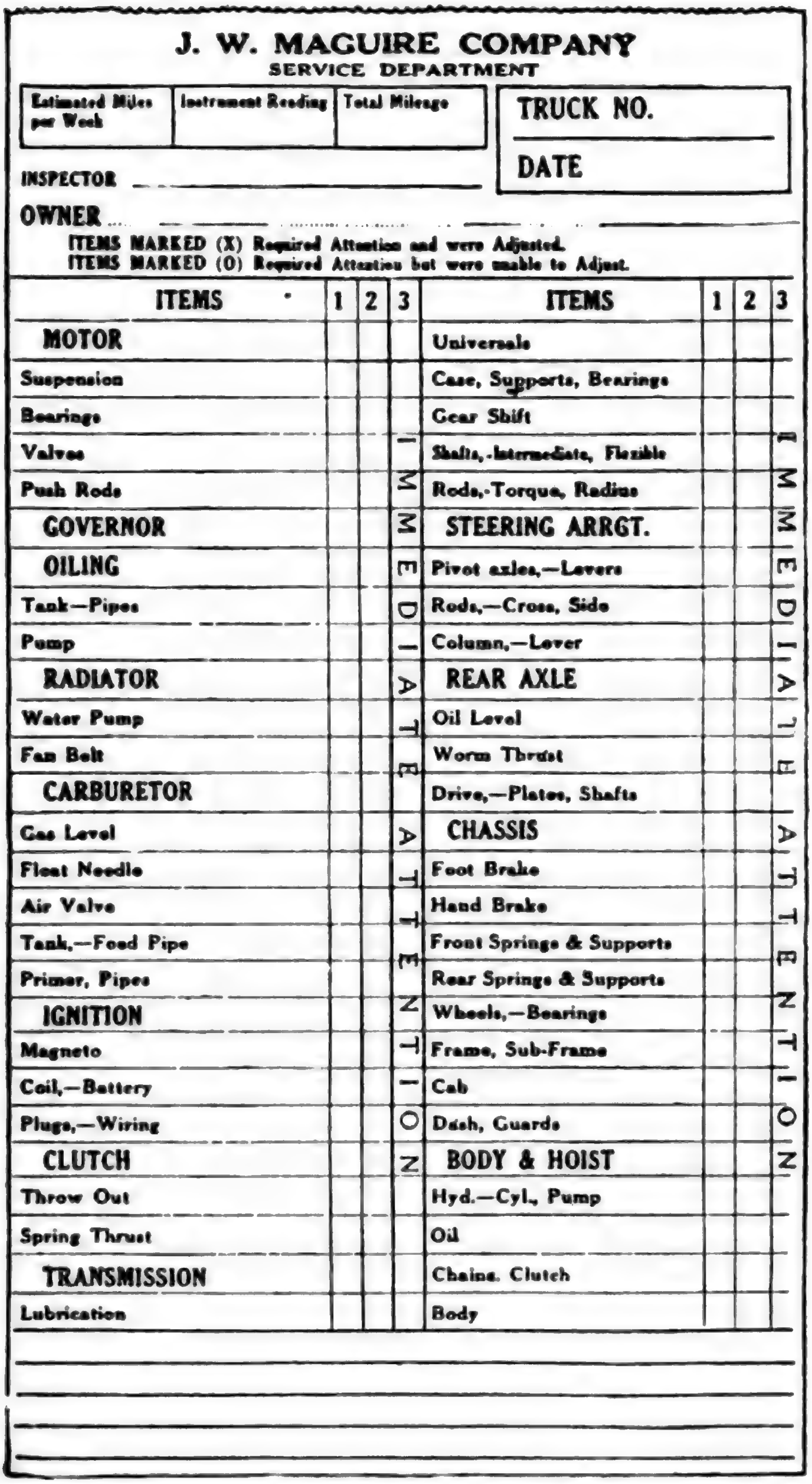
There are upwards of seven hundred Pierce-Arrow trucks in the Maguire company's territory, and all of these are inspected save the large fleets that are under the supervision of distinct organizations. In other words, the system benefits all owners who have not their own service stations and expert mechanics. The inspecting is done by two men, one who covers Boston and its suburbs, and the other the outlying territory within a radius of sixty miles, they examining the trucks approximately once a month, and those at greater distances are inspected from four to six times a year. The men have no regular schedule for their work, but arrange their daily itineraries so that they will meet the trucks in service and drive and examine them so far as may be necessary to learn every detail required in the record.

System is Very Thorough.—The accompanying illustration of a report form shows that the examination covers the engine, governor, oiling system, radiator, carburetor, ignition system, clutch, transmission system, steering gear and linkage, rear axle, chassis and body and hoist. Each of these covers different items and collectively they include practically every construction unit and part. The inspector examines the machines systematically and careful attention is given to adjustment and to lubrication.

Emphasis is made that the chassis must be oiled and greased to what is known as the Pierce-Arrow standard, and that unless this care is given there will be destructive wear that will be reflected in expensive upkeep and increased cost of operation and greatly lessened service life. The report indicates the units and parts that required attention and were adjusted, and those which were not adjusted, this applying to work that could not be done with hand tools and which must be done in a shop or garage with more complete facilities. These are shown in the first and second columns of the report form. In the event that work is imperatively necessary this is noted in the third column. This, however, is seldom done.

Report Made in Triplicate.—The report is made in triplicate on two white and one salmon color sheets. The inspector sends one white and the salmon sheet to the office of the company and retains the second white sheet in his record book. In the event that small replacements are made by the inspector from a stock he carries with his tool kit, these are noted on the report and from these notes charges are made the owner. Unless the inspector makes replacements, there is no cost attached, and then only the prices of the parts.

The reports are carefully analyzed and copies are sent the owners, and when necessary they are accompanied by such recommendation as will insure the care and maintenance as well as increase the average service life of the vehicles. In the event that a condition is such that a change in care is desirable the reports are noted each month and the owners are informed whether or not there is improvement. The owner is advised that he can make a change. No responsibility is placed, that



J. W. MAGUIRE COMPANY
SERVICE DEPARTMENT

Estimated Miles per Week	Instrument Reading	Total Mileage

TRUCK NO.

DATE

INSPECTOR

OWNER

ITEMS MARKED (X) Required Attention and were Adjusted.
ITEMS MARKED (O) Required Attention but were unable to Adjust.

ITEMS	1	2	3	ITEMS	1	2	3
MOTOR				Universals			
Suspension				Case, Supports, Bearings			
Bearings				Gear Shift			
Valves			I	Shafts,-Intermediate, Flexible			I
Push Rods			M	Rods,-Torque, Radius			M
GOVERNOR			M	**STEERING ARRGT.**			M
OILING			E	Pivot axles,—Levers			E
Tank—Pipes			D	Rods,—Cross, Side			D
Pump			I	Column,—Lever			I
RADIATOR			A	**REAR AXLE**			A
Water Pump			T	Oil Level			T
Fan Belt			E	Worm Thrust			E
CARBURETOR				Drive,—Plates, Shafts			
Gas Level			A	**CHASSIS**			A
Float Needle			T	Foot Brake			T
Air Valve			T	Hand Brake			T
Tank,—Feed Pipe			E	Front Springs & Supports			E
Primer, Pipes				Rear Springs & Supports			
IGNITION			N	Wheels,—Bearings			N
Magneto			T	Frame, Sub-Frame			T
Coil,—Battery			I	Cab			I
Plugs,—Wiring			O	Dash, Guards			O
CLUTCH			N	**BODY & HOIST**			N
Throw Out				Hyd.—Cyl., Pump			
Spring Thrust				Oil			
TRANSMISSION				Chains, Clutch			
Lubrication				Body			

Fig. 525.—The Inspection Record of the J. W. Maguire Co., Filled in Triplicate, a Copy of which, with Recommendation, is Sent to the Owners Monthly.

being left to the owner to determine. But he is informed that he will be the loser if the truck is not kept adjusted and lubricated.

Neglect of Truck is Shown.—The inspection reports also establish whether or not the trucks have been neglected, and should there be claim made relative to a condition for which the manufacturer is maintained by the owner to be responsible the reports will be the basis of judgment. The other report is filed, the one for comparison by months or periods and the inspectors' books are kept for reference.

The inspectors do emergency work in the sense that the one may be assigned to the other's territory to do what may be imperatively necessary, and frequently what may be begun by one man is completed by the other, so there is the judgment of two men instead of one to be applied to the condition of the truck or trucks on which they work. The reports are made impartially and there is no reason for the drivers to feel that they are not fairly dealt with. In fact, they are made to understand that if they are guided by the advice of the inspectors their work will be made easier and they will be more efficient employees.

Inspectors Ride on Trucks.—The inspectors necessarily have to drive the trucks to learn their condition and considerable to their traveling is on the machines. For this reason they cannot use cars to good advantage, for they would have to leave the machines whenever a truck was inspected and return considerable distances to them. This would reduce the time they now give to work, and by their knowledge of the owners' service they can arrange to meet and leave trucks so that practically no time is lost.

The Maguire Company has at times found owners indifferent and in rare instances antagonistic to accepting inspection. They are informed that his service is what they have paid for and entitled to when a truck is delivered and that the purpose is to insure to them continued utility of the machines at the lowest possible cost. They learn by practical experience that they substantially benefit and that there is varying economy obtainable if they will follow advice that is based on careful study of the reports. The inspection is continued without regard to the period of service.

The inspection service of the Pierce-Arrow Company is also a check that can be studied to advantage. The main object is to follow the manner of lubrication, for statement is made if this is done systematically there will be without doubt a good knowledge of the mechanical condition and adjustment and restoration whenever needed.

VIM SERVICE STATION SYSTEM

Greatly simplifying the recording and tracing of repair work is the job system of the Vim Motor Truck Co., of Philadelphia, maker of Vim trucks. Statement is made that dealers regard it with increasing favor because of the "workableness" of the system, whereby the inspector makes out in triplicate a "Service Work Order," this being a white sheet signed by the owner of the car to be repaired and retained by him until he calls for his car, when he surrenders it. This form is known as the "Car Sheet." The buff copy of the service goes to the storekeeper and indicates what work has been done.

A manila "Work Card," having a brass-rimmed perforation at the top through which string is to be run to tie it to the steering wheel of the vehicle to be repaired, or to the part to be restored or exchanged, as a tag, is not to be removed until the work has been completed. When the work has been finished, this tag, with other data covering the job, such as the "Work Sheet," "Time Cards," "Requisitions" and a copy of the invoice, or release bearing the job number, are placed in the job envelope and presented to the cashier. The envelope, with its contents, is filed under the owner's name, fitting in a pigeon hole for the purpose, the shop clerk having so placed the job that by a hurried inspection of the envelopes in the various pigeon holes he can learn how much time has been put on any particular job.

Cashier Must Release Machine.—Instructions are given that before delivering a truck, or repair job to the owner, or driver, a receipted invoice, or release, must be obtained from the cashier. This is a positive check on any confusion about whether a car should be removed, or whether it has been so removed. Under no circumstances, under the Vim system of records, will verbal orders in this regard be accepted.

Tied on the steering wheel of the vehicle, or the part to be repaired, the manila tag of the series in triplicate shows what is to be billed and the bills also are placed in the pigeon hole under the owner's name, with the job envelope. By strict adherence to this rule there is "a place for everything and everything in its place."

After the job has been billed, the form on the outside of the envelope is filled in—motor number, name and address of car owner, as well as invoice date and ledger page, and the envelopes are filed. The removal of an envelope from a shop pigeon hole to a file is proof that the bill has been sent out.

No. Date

Owner

Est. Hrs. Time Promised

Total Time Amount

	On	Man's No.	Man's No.	On	
	Off			Off	
	On			On	
	Off			Off	
	On			On	
	Off			Off	

Fig. 526.—Workman's Time Card Employed in Vim Service Station System.

History Card Shows Condition.—A "History Card" taken of each truck repaired serves a purpose for future reference, as such a record will tell what has happened to the truck, by number as well as owner's name, through: (a)—Accident. (b)—Abuse. (c)—Net Depreciation.

This "history" is indicative of the truck's condition and of the type of person driving it. It shows, in a way, what to expect.

With regard to the buff copy of the triplicate series, which is in possession of the storekeeper:

After the job number, name, address, date, chassis number, model, time of delivery, estimated price and signature for authorization of work to be done have been filled in, the sheet is placed in the "Job in Action" rack, where it must be retained until the work has been completed. It is necessary that the bill number for the work and the date the machine was delivered be placed in the spaces provided therefor, having all of the foregoing totaled and checked, with the person's signature showing in a special space also provided. When the work has been completed, as already mentioned, this form, with others, is presented to the cashier.

Motor No. ....Job No..................

Chassis No. ....Date....................

Name ....

Address ....

....

....

This Job Envelope contains the following:

Work Card
Work Sheet
Time Cards
Requisitions
Copy of Invoice

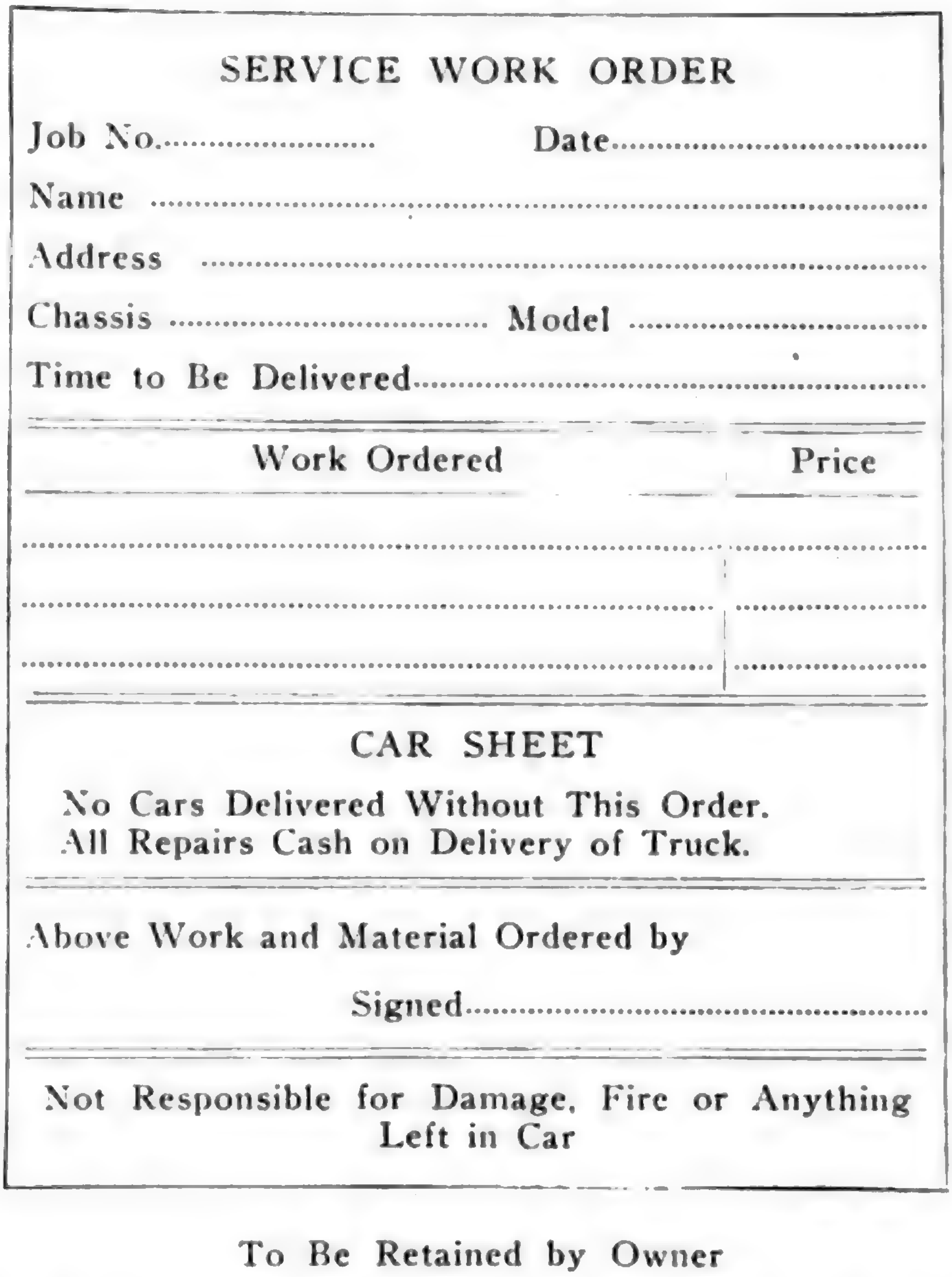
Invoice Date ....Ledger Page............

To Be Filed in Job Envelope File Under Owner's Name.

Fig. 527.—Form to Be Printed on Job Envelope in Vim Service Station System.

With regard to the "Car Sheet," retained by the owner until the car is called for, the owner is requested on the back of this form to cooperate with the Vim service in various ways, such as allowing the Vim company to properly instruct the driver, and using only the best lubricants on the machine.

Value of Requisition Forms.—In making out requisition forms the dealer, of course, keeps one and sends a buff duplicate to the factory. A rule is that no orders will be filled unless part and chassis numbers are furnished with requisition. In addition, the following procedure is required: Give the quantity required; but for telegraph orders, the number only, or the code word can be given.



SERVICE WORK ORDER

Job No.......................... Date....................................

Name ....

Address ....

Chassis .... Model ....

Time to Be Delivered...

Work Ordered	Price
....	....
....	....
....	....

CAR SHEET

No Cars Delivered Without This Order.
All Repairs Cash on Delivery of Truck.

Above Work and Material Ordered by

Signed...

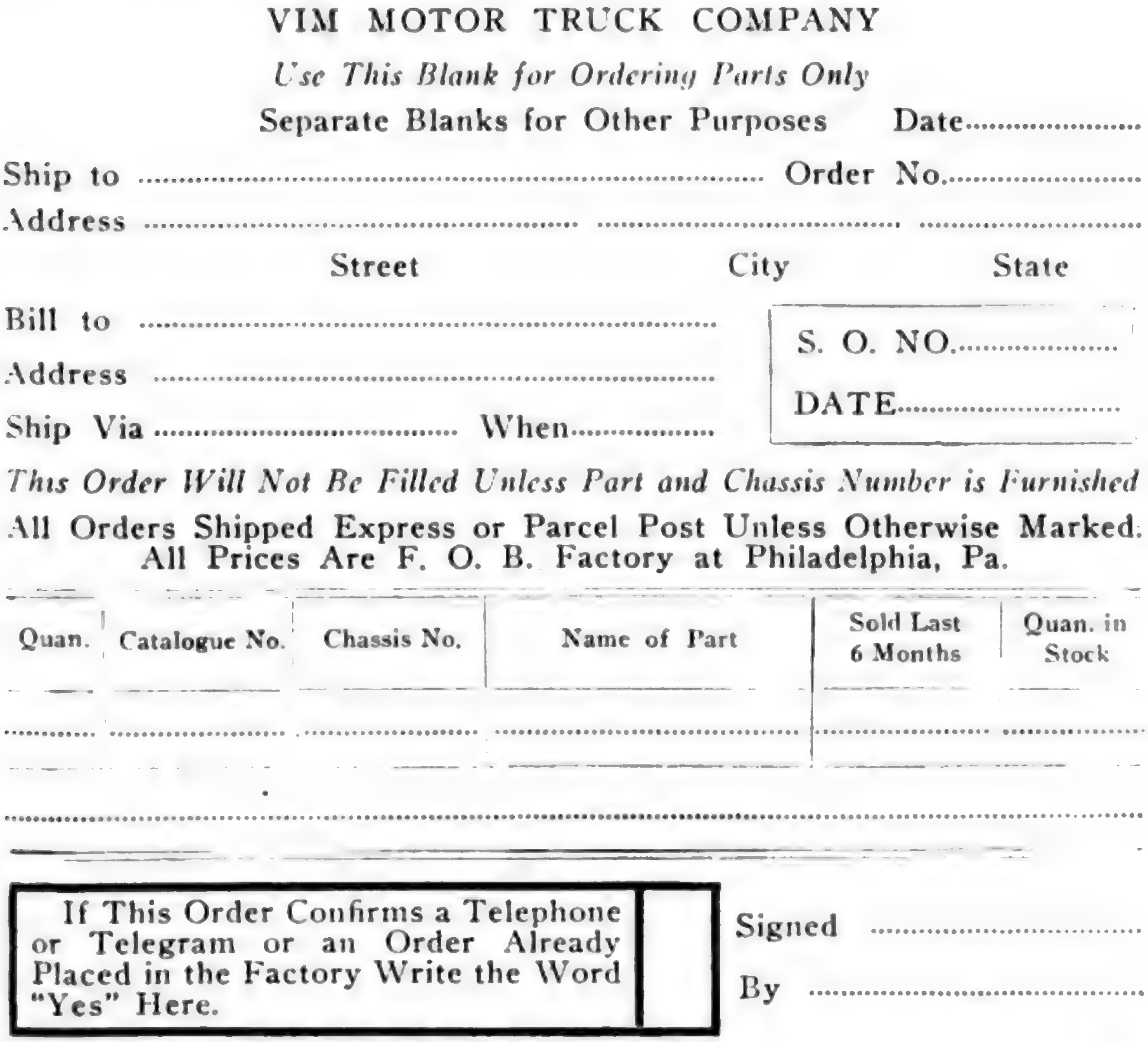
Not Responsible for Damage, Fire or Anything Left in Car

To Be Retained by Owner

Fig. 528.—Service Work Order, Ruled for 15 Entries and Total, Made in Triplicate on White and Buff Sheets and Manila Card, 5½ by 8¼ Inches.

If there is any doubt as to the correct name, or description of the parts wanted, the dealer is instructed to ship the old parts to the factory, or the nearest service station, transportation charges prepaid, so that they can be duplicated. This is regarded as an especially safe way. There is a special form in triplicate—green, buff and white sheets—used for the return of Vim parts.

When shipping parts as samples the dealers are advised to tag each part with the purchaser's name and address and notify the factory, or the nearest service station by letter, at the same time stating that parts are being sent as samples, giving the number of duplicates required and how they are to be shipped, as well as stating if the samples sent are to be returned with the new parts. It is always advisable to order parts from nearest Vim truck distributor, or service station, to insure prompt shipments and minimum transportation charges.



VIM MOTOR TRUCK COMPANY

Use This Blank for Ordering Parts Only

Separate Blanks for Other Purposes Date....................

Ship to .... Order No.......................

Address ....

Street City State

Bill to ....

Address ....

Ship Via .... When.................

S. O. NO....................

DATE.........................

This Order Will Not Be Filled Unless Part and Chassis Number is Furnished

All Orders Shipped Express or Parcel Post Unless Otherwise Marked.
All Prices Are F. O. B. Factory at Philadelphia, Pa.

Quan.	Catalogue No.	Chassis No.	Name of Part	Sold Last 6 Months	Quan. in Stock

If This Order Confirms a Telephone or Telegram or an Order Already Placed in the Factory Write the Word "Yes" Here.

Signed ....

By ....

Fig. 529.—Parts Requisition Sheet, Made in Duplicate on White and Buff Sheets, the Former Being Retained by the Dealer and the Latter Sent to the Factory. Size 8½ by 11 Inches.

Instruction for Parts Disposal.—It is a rule of the company that under no circumstances will parts be shipped for replacement, unless the original parts are returned, transportation charges prepaid, to the factory for an inspection and the claim for each replacement has been approved by the engineering department. When the parts are shipped for inspection each part must be tagged with the shipper's name and address and the chassis number of the truck from which it has been removed. When replacement of parts is denied, inspected parts are subject to the shipper's orders for disposition when returned and the Vim Motor Truck Co. does not become responsible for parts not accompanied with instructions for disposition if credit is denied.

VIM MOTOR TRUCK COMPANY

Philadelphia, U. S. A.

Factory R. P. R. No. .... Date..................................

Vim Truck Parts Returned by..

Address ....

Quantity	Part No.	Description of Parts Returned	Chassis No.	Date of Invoice	No. of Invoice
....	....	....	....	....	....
....	....	....	....	....	....
....	....	....	....	....	....

Credit will not be considered Unless All Information called for is given.

Owner's Name ....

Address ....

No. of Miles Truck Has Been Run..........................

Why Credit Is Claimed ....

....

....

If Credit or Replacement Is Denied What Disposition Is to Be Made of Parts: ....

....

....

(Signed)..

3. Retain This Copy.

Fig. 530.—Parts Return Sheet, Made in Triplicate on Green, White and Buff Sheets, the White Being Retained by the Dealer and the Others Sent to Factory. Size 8½ by 11 Inches.

The Vim company guarantees new Vim vehicles to be free from defects in material and workmanship for ninety days from date of delivery to the purchaser, will be made if such parts are returned for credit or replacement and the company finds them defective. Tires, rims, batteries, speed instruments and other accessories are not covered by this warranty.

The method of use of the special form in triplicate—green, buff, and white—designed for the return of parts, is as follows:

The dealer retains the white, or third sheet of the series. He fills out form number one, or the top green sheet and, using a carbon, the buff sheet, or form number two, and sends them both to the factory.

The ideal condition from the factory viewpoint is to supply the dealer with the requisite initial stock, sufficient for his particular territory from a list based on the demands from that county, or local tract. Once a dealer actually gauges his stock, or gets a stock well balanced according to demand, orders on the factory becomes mere requisitions on stock.

In the case of small garages supplied, little tags are used instead of the requisition sheet. These tags bear the part number and the job number, with the price of the part, and such tags serve as a basis on which to replenish stock.

TRUCK AND TRAILER LAWS

A special committee, composed of representatives from the American Association of State Highway Officials, the National Automobile Chamber of Commerce, the American Automobile Association and the Highways Industrial Association, drafted a proposed uniform vehicle law in which are embodied suggestions regarding the sizes and weights of vehicles using the highways. The proposed restrictions provide for a maximum overall width of vehicle of 96 inches, a maximum overall height of 12 feet, 6 inches, a maximum overall length for single vehicles of 30 feet and for combinations of vehicles of 85 feet; a maximum gross weight of 14 tons, distributed so that not more than 22,400 pounds shall rest on any one axle nor more than 800 pounds on each inch of tire width as measured between the flanges of the rim. No restrictions would be placed on the number of trailers that might be hauled by a truck or tractor as long as the restriction on the length of road trains were not exceeded, and officials would be allowed to issue special permits for the operation of prohibited vehicles over highways under their control. It is contended in behalf of the proposals that they are sufficiently liberal to allow owners to take advantage of the economies which result from the use of larger haulage units, yet sufficiently low to safeguard traffic and to protect highway surfaces and foundations from destruction.

A digest of existing state laws governing the size and weight of motor vehicles and the number of trailers is given in the following paragraphs, which are reprinted from the "Power Wagon," of Chicago. Where no state laws have been enacted covering these points, local ordinances may govern, but generally these are not allowed to conflict with state laws where the latter touch the same subject-matter. All dimensions and weights are maxima, and all tons are of 2,000 pounds. Size restrictions are shown first, weight restrictions next, trailer restrictions third and permit provisions last:

Alabama.—No state law.

Arizona.—No state law.

Arkansas.—No state law.

California.—(1) Outside width of track 112 inches; outside width of bed of vehicle and load 102 inches.—(2) Gross weight of 4-wheeled vehicle 15 tons; gross weight of 6-wheeled outfit, having its three axles at least 96 inches apart, 20 tons; weight per inch of tire width 600 pounds with metal tires, 800 pounds with other than metal tires. The State Department of Engineering may reduce these limits on bridges, viaducts, etc. (3) Number of trailers 2.—(4) On written application State Department of Engineering may grant permits to operate heavier or wider loads or more than 2 trailers, or to increase the permissible wheel weights.

Colorado.—No state law.

Connecticut.—(1) Overall width 114 inches.—(2) Gross weight 12½ tons; weight per inch of tire width 500 pounds on metal tires, 700 pounds on other tires. State Highway Commissioner may restrict use of commercial motor vehicles of over 4-ton capacity on trunk lines or state-aid highways.—(3) Number of trailers not limited.—(4) On written application State Highway Commissioner, or other authority having charge of the repair or maintenance of any highway or bridge, may grant permits allowing operation of prohibited vehicles.

Delaware.—(1) Width of vehicle 96 inches, height 146 inches.—(2) Gross weight 13 tons; weight per inch of tire width 700 pounds; gross load of metal-tired trailers 3 tons.—(3) Number of trailers not limited.—State Highway Department may issue special permits to operate vehicles exceeding weight limits.

District of Columbia.—(1) Size not limited.—(2) Gross weight on bridges with wood floors 6 tons, on any other bridges 15 tons.—(3) Number of trailers 1.—(4) Engineer Commissioner may issue written permits for operation of heavier vehicles over bridges.

Florida.—No state law.

Georgia.—No state law.

Idaho.—No state law.

Illinois.—(1) Width of vehicle and load 96 inches; total length of vehicle and trailers 65 feet.—(2) Gross weight 8 tons for one axle; weight per inch of tire width (as measured at the line of contact of the tire with the road) 800 pounds.—(3) Number of trailers not limited, except by section 1.—(3) Highway officials may grant permission for operation of heavier vehicles or longer road trains.

Indiana.—(1) Size not limited.—(2) Weight 10 tons capacity.—(3) Number of trailers not limited.—(4) Special permits not mentioned.

Iowa.—(1) Width of vehicle and load 96 inches.—(2) Gross weight of vehicle and load 14 tons; weight per wheel 4 tons; weight per inch of tire width (as measured at the line of contact of the tire with the road) 800 pounds on hard-surfaced highways and 400 pounds on earth, gravel or similar surfaces.—(3) Number of trailers not limited.—(4) Special permits not mentioned.

Kansas.—No state law.

Kentucky.—(1) Size not limited.—(2) Gross weight 15 tons; weight per inch of tire width (as measured at the line of contact of the tire with the road) 500 pounds for metal tires and 800 pounds for other tires.—(3) Number of trailers not limited.—(4) Special permits not mentioned.

Louisiana.—No state law.

Maine.—(1) Size not limited.—(2) Gross weight 9 tons; weight per inch of tire width 800 pounds.—(3) Number of trailers not limited.—(4) Highway officials may permit operation of heavier vehicles over highways under their control.

Maryland.—(1) Width of vehicle 90 inches.—(2) Gross weight 10 tons; weight per inch of tire with 650 pounds. Vehicles rated to carry more than 5 tons not registrable.—(3) Number of trailers not limited.—(4) Highway officials may grant permission to operate heavier vehicles on highways subject to their control.

Massachusetts.—(1) Width 96 inches; length of single vehicle 28 feet; total length of a combination of vehicles 65 feet.—(2) Gross weight 14 tons; weight per inch of tire width 800 pounds.

—(3) Number of trailers not limited.—(4) Highway officials may grant permission to operate heavier or larger units over highways under their jurisdiction.

Michigan.—(1) Track of trucks and trailers 75 inches between tire center-lines; overall width 96 inches; overall height 150 inches; aggregate length of a combination of vehicles 60 feet.—(2) Weight per wheel 700 pounds for tires 2 inches wide up to 3,200 pounds for tires 7 inches wide on wheels 36 inches in diameter. These maxima are larger for wheels of greater diameter, those for 44-inch wheels being 1.6 times those for 36-inch wheels.—(3) Number of trailers 2.—(4) Special permits not mentioned.

Minnesota.—No state law.

Mississippi.—No state law.

Missouri.—No state law.

Montana.—No state law.

Nebraska.—No state law.

Nevada.—No state law.

New Hampshire.—No state law.

New Jersey.—(1) Length 26 feet 6 inches; width 92 inches; height 150 inches.—(2) Gross weight 15 tons; weight per inch of tire width 800 pounds.—(3) Number of trailers 1.—(4) Highway officials may issue permits for operation of prohibited vehicles over highways under their jurisdiction.

New York.—(1) Overall width 96 inches; height 150 inches. (Outside cities.)—(2) Gross weight 12½ tons; weight per inch of tire width 800 pounds. (Outside cities.)—(3) Number of trailers not limited.—(4) Special permits not mentioned.

North Carolina.—(1) Size not limited.—(2) Weight 5½ tons capacity.—(3) Number of trailers not limited.—(4) Special permits not mentioned.

North Dakota.—No state law.

Ohio.—(1) Size not limited.—(2) Weight per inch of tire width (as measured between the flanges of the rim) 800 pounds for rubber tires of all sizes, 500 pounds for iron or steel tires up to and including those 12 inches wide and 800 pounds for metal tires more than 12 inches wide.—(3) Number of trailers not limited.—(4) Special permits not mentioned.

Oklahoma.—No state law.

Oregon.—(1) Size not limited.—(2) Weight 5 tons carrying capacity; weight per inch of tire width 600 pounds.—(3) Number of trailers not limited.—(4) Special permits not mentioned.

Pennsylvania.—(1) Overall width 90 inches; overall length 28 feet.—(2) Gross weight 13 tons; weight per axle 19,500 pounds; weight per inch of tire width 800 pounds.—(3) Number of trailers 1.—(4) State Highway Commissioner may issue permits for operation of prohibited vehicles or more than one trailer.

Rhode Island.—(1) Size not limited.—(2) Gross weight of trailer 2 tons.—(3) Number of trailers not limited.—(4) State Board of Public Roads may issue permits for heavier trailers.

South Carolina.—(1) Size not limited.—(2) Weight 4 tons capacity.—(3) Number of trailers not limited.—(4) Highway authorities may grant permit for operation of heavier vehicles.

South Dakota.—No state law.

IMPORTANT NOTE

Cost determination figures and digest of laws are subject to change from time to time. These are given as a guide only, and must be verified by checking up local conditions. What was true at the time of writing may have been altered materially by changed conditions shortly after time of printing.

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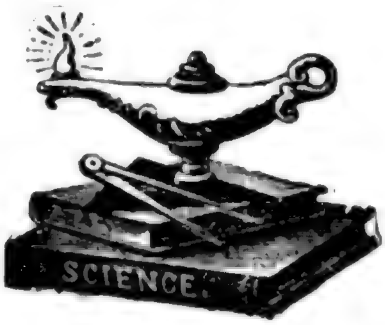

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This book is the standard and latest work published on the subject and has been prepared for the use of all engaged in the business of steam, hot-water heating, and ventilation. It is an original and exhaustive work. Tells how to get heating contracts, how to install heating and ventilating apparatus, the best business methods to be used,

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